NEST-SITES, NESTING SUCCESS, AND TURNOVER-RATES OF WHITE-HEADED WOODPECKERS

ON THE DESCHUTES AND WINEMA NATIONAL FORESTS, OREGON IN 2002

By

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Abstract: From 3 May to 27 June 2002, I searched for nests of white-headed woodpeckers (*Picoides albolarvatus*) on 9 study areas in predominantly ponderosa pine (*Pinus ponderosa*) or dry mixed conifer forest-types: 4 study areas on the Deschutes National Forest, and 5 study areas on the Winema National Forest. The amounts of old-growth forest within these study areas ranged from 0 to 98%. From 1997 to 2001 I located 262 active nests at 100 different territories of white-headed woodpeckers on or near these study areas.

In 2002 I found 55 active nests of white-headed woodpeckers: 36 on the Deschutes National Forest at elevations ranging from 884 to1244 m, and 19 on the Winema National Forest at elevations ranging from 1408 to 1676 m. Occupancy of previously known territories in 2002 was 57.6%. Occupancy of known territories has diminished 4.3% to 13.2% each year since 1998.

Forty-three of the nests found in 2002 were in ponderosa pine forest-type, 4 were in mixed pine forest-type, and 8 were in dry mixed conifer forest-type. I found 72.7% of the nests in previously harvested sites: 7 in partial cuts, 12 in shelterwoods or seed tree cuts, 9 in overstory removals, 7 in clearcuts, and 5 in commercial thins. Fifteen of the nests were in relatively open spots in virtually uncut stands. The Metolius study area had the highest density of white-headed woodpeckers. In 2002, the Metolius study area had a minimum density of 0.43 nests/40 ha. Density of nests on the Metolius study area from 1999 to 2001 was 0.72 nests/40 ha; in 1998 I found a minimum density of 1.08 nests/40 ha at this site.

In 2002 all but 2 of the 55 nests of white-headed woodpeckers I found were in completely dead trees. Dbh of the nest-trees ranged from 23.6 to 118.1 cm; average dbh of the nest-trees was 70.9 ± 6.6 cm CI. Forty-nine of the nest-trees (89.1%) were ponderosa pines. Condition of the nest-trees was variable: 3.6% were live or partially dead trees, 16.4% were recently dead trees, 69.1% were middle-aged snags, and 10.9% were older or decrepit snags. Six of the nest-trees were stumps of harvested trees. Heights of nest-cavities found in 2002 ranged from 0.67 to 22.0 m (mean = 3.41 ± 0.67 m CI, n = 55). Most of the cavities (87.3%) had freshly excavated entrances; but at least 7 (12.7%) of the nests were in old or re-excavated cavities or had entrances excavated in previous years.

I found the white-headed woodpeckers nesting in relatively open sites. Canopy-closure at the nest-trees found in 2002 ranged from 0% to 57% (mean = 13.3 ± 4.2% CI). Average density of trees >21" dbh (53 cm) at nest-sites was 6.8 ± 1.7 trees/0.4 ha CI (range: 0 – 24). Average density of snags >6" dbh at nest-sites was 4.4 ± 1.6 snags/0.4 ha CI (range: 0 – 31).

I estimated that successful nests in 2002 fledged an average of 2.58 young per nest (2.27 – 2.88 CI, range: 1-4, n = 26). Using the Mayfield method I estimated nesting success in 2002 was 54.5% (42.0 – 70.6% CI). Estimated nesting success on the study areas in 1997-2001 ranged from 22.9 to 57.9%.

Nests from 1997 through 2002 at sites with high densities of large-diameter trees (>21" dbh) had a significantly higher survival than nests in recently cut sites ($P < 0.001$). Nest-sites that were in uncut stands or had densities of large trees =12 trees/acre, had an estimated success-rate of 59.6% (48.7 – 72.9% CI; $n = 80$); nests at previously harvested sites had an estimated success-rate of 37.6% (31.7 – 44.7% CI; $n = 237$).

At the end of the 2001 nesting season I knew of 60 surviving color-marked white-headed woodpeckers on the study areas. I estimated adult survivorship from 2001 to 2002 was 0.70. Mean estimated annual survivorship from 1997 to 2002 (5 years) was 0.64. Assuming a closed population, the productivity and adult survivorship at the study areas from 1997 through 2002 are inadequate to maintain population replacement. The estimated nesting success (mean = 42.7%) and fledglings per successful nest (mean = 2.42, $n = 110$) from 1997 through 2002 would require a juvenile survival rate of 0.703 to offset the adult mortality estimated in this study. This required juvenile survival for population maintenance is greater than the adult survival estimated in this study.

The components of the habitat affecting densities, reproductive success, and survivorship of white-headed woodpeckers are not completely understood. The proportion and distribution of relatively open areas that provide nesting sites for this species appear to be important. Degradation of habitat quality from increased shrub cover and understory layers may account for low densities of white-headed woodpeckers in some study areas that have extensive tracts of large ponderosa pine. White-headed woodpeckers may be attracted to areas with openings created by silvicultural treatments; however, the nesting-success of white-headed woodpeckers at these sites is depressed. Nesting success of white-headed woodpeckers in central Oregon appears to vary widely from year to year. The effects of years with low survival and productivity on population stability, and its relationship to habitat quality, can not be determined without continued monitoring of the nesting birds.

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INTRODUCTION

The distribution of the white-headed woodpecker (*Picoides albolarvatus albolarvatus*) is limited to montane coniferous forests in the far western United States and south-central British Columbia (Garrett et al. 1996, Marshall 1997). The food habits of white-headed woodpeckers separate them ecologically from other *Picoides* (Ibid.; Dixon 1995a, 1995b). When feeding on invertebrates, white-headed woodpeckers mostly forage by gleaning and flaking on the surfaces of the trunk, branches, and needle clusters of live trees; they rarely drill beneath the surface or into dead wood. White-headed woodpeckers in some areas also are seasonally dependent on seeds of large-coned pines such as ponderosa pine (*Pinus ponderosa*) or sugar pine (*P. lambertiana*) for a portion of their diet. The birds do not feed extensively on seeds of small-coned pines such as lodgepole (*P. contorta*), and are not commonly found in forests dominated by that species.

White-headed woodpeckers are associated with ponderosa pine throughout most of their range, and appear to prefer relatively open stands with little understory and low shrub cover (Garrett et al. 1996, Marshall 1997). The presence of old-growth pine is thought to be important to white-headed woodpeckers. Larger pines provide large surface areas for the invertebrate prey of white-headed woodpeckers and are good cone producers; old-growth stands also have greater densities of the large-diameter snags that white-headed woodpeckers appear to select for nesting (Ibid.).

In Oregon, Rita D. Dixon (1995a, 1995b) studied white-headed woodpeckers in 1991 and 1993 on the Winema, Deschutes, and Ochoco National Forests. She reported that white-headed woodpeckers selected home ranges dominated by old-growth ponderosa pine. White-headed woodpeckers were largely absent from her study areas that were predominantly mixed conifer forest or in younger seral stages. She found, however, that some study areas containing extensive tracts of old-growth ponderosa pine were unoccupied or had low densities of nesting white-headed woodpeckers.

Harvesting of mature ponderosa pine stands in Oregon has markedly reduced the amount of habitat for white-headed woodpeckers, and a history of fire suppression may have degraded the quality of the remaining habitat (Marshall 1997). Recent summaries of the current knowledge of white-headed woodpeckers (Garrett et al. 1996, Marshall 1997) have identified studies on breeding dynamics and long-term population monitoring as research priorities for the species.

Based on the narrow habitat requirements of the species and because of the loss and fragmentation of the habitat, the Oregon Department of Fish and Wildlife (ODFW) listed the white-headed woodpecker as critical on its sensitive species list (ODFW 1995). The U.S. Fish and Wildlife Service (USFWS) listed the white-headed woodpecker as a Species of Concern, and the Bureau of Land Management (BLM) lists it as a Sensitive Species in Oregon. Oregon-Washington Partners in Flight identified the white-headed woodpecker as a focal species for conservation representative of large patches of late-successional dry forest habitats. Oregon-Washington Partners in Flight has also listed the white-headed woodpecker as a Special Species requiring population monitoring in the Special Species Landbird Monitoring Strategy.

White-headed woodpeckers are also listed as a Protection Buffer species in both the Northwest Forest Plan SEIS (USDA and USDI 1994, p.C-46) and the Survey and Manage SEIS (USDA and USDI 2000, pp.65, 368-369). The Science Assessment for the Interior Columbia Basin Ecosystem Management Project (Wisdom et. al 2000, pp.136, 166) identifies the white-headed woodpecker as a species of focus. The Source Habitat Analysis places the species in a family dependent on low-elevation, old-forest habitats - one of the habitats with the strongest declines from historic levels.

This study is a continuation of research on nesting white-headed woodpeckers I conducted on the Winema and Deschutes National Forests in 1997 - 2001 (Frenzel 1998, 1999a, 1999b, 2000, 2001). The objectives of this study were to: 1) describe the nesting sites of white-headed woodpeckers; 2) estimate their nesting success; and 3) continue to color-mark white-headed woodpeckers to allow study of site-tenacity, pair-bond longevity, and survival. In 1997 and 1998 this research on nesting white-headed woodpeckers was conducted in conjunction with surveys to estimate densities of white-headed woodpeckers and other woodpeckers on the same study areas (Frenzel and Popper 1998a, 1998b).

STUDY AREAS

I selected 10 study areas in predominantly ponderosa pine or dry mixed conifer forest-types: 4 on the Deschutes National Forest, and 6 on the Winema National Forest (Figure 1). Eight of these study areas are described by Dixon (1995a, 1995b): Black Butte, Cold Springs, First Creek, and Metolius on the Deschutes National Forest; and Blue Jay, Doe Butte, Wildhorse Ridge, and Yoss Ridge on the Winema National Forest. These study areas are predominantly ponderosa pine forest-type. The amount of old-growth forest within these study areas ranges from 0% to 98%. I selected these study areas either because Dixon reported a measurable density of white-headed woodpeckers or because the area appeared to be potential habitat for the species. I altered the perimeter of the Black Butte study area to reduce its proportion of non-forested habitat: I eliminated the portion south of Highway 20 and expanded the northern and western boundaries.

Boundary Butte study area

In 1997 I established a new study area near Boundary Butte (42°47'N, 121°53'W; T.32S, R.7E) on the Chemult Ranger District of the Winema National Forest, approximately 23 km north of Chiloquin, Oregon. At least 5 sightings of white-headed woodpeckers were reported in the Boundary Butte area during 1990-1995 (Todd Forbes, pers. comm.). The 1235 ha study area ranges from 4600 to 5220' (1405 - 1595 m) in elevation. The area is predominantly dry mixed conifer forest-type (75%); dominants in the canopy are Shasta red fir (*Abies magnifica* var. *shastensis*) and/or white fir (*A. concolor*) with inclusions of ponderosa pine, sugar pine, lodgepole pine, and western white pine (*Pinus monticola*). The remainder of the study area is ponderosa pine forest-type (17%) or lodgepole pine forest-type (8%). The shrub layers within the study area are dominated by bitterbrush (*Purshia tridentata*), manzanita (*Arctostaphylos uva-ursi*), snowbrush (*Ceanothus velutinus*), or chinquapin (*Castanopsis*

chrysophylla). Needlegrass (Stipa thurberiana) or sedges (Carex spp.) usually dominate the herbaceous layers.

Logging in the Boundary Butte area during the1920's removed much of the large ponderosa pine, and harvesting during the late 1940's took additional ponderosa pine and many of the large Shasta red fir. This harvesting and the exclusion of fire from the area during the past 90 years has resulted in an overstocked understory and increased dominance of true firs and lodgepole pine. A long standing forest-sanitation program in the area reduced the densities of large snags and large down wood in many of the stands (Terry Simpson, pers. comm.).

Approximately 50.4% of the Boundary Butte study area is in various silvicultural treatments from the 1970's and 1980's - mostly overstory removals and seed tree cuts at dry mixed conifer sites. Approximately 22% of the study area is very late seral dry mixed conifer with adequate densities of large trees for classification as old-growth (Hopkins et al. 1992a, 1992b); however, only 0.3% of the study area also has verified densities of large snags and large down wood to meet old-growth definitions. An additional 2.8% of the study area is late seral dry mixed conifer, and 3% of the area is in middle seral dry mixed conifer. Approximately 5.4% of the area is comprised of very late seral ponderosa pine; these stands have adequate densities of large trees to meet old-growth definition, but lack large wood decadence. An additional 8.7% of the area is comprised of late seral ponderosa pine. Late or very late seral lodgepole pine forest comprises 7.5% of the area. There are stands of large trees dominated by sugar pine located at Dry Butte approximately 6.5 km north of the study area (Terry Simpson, pers. comm.).

Desert Creek study area

In 1998 I established a new study area north of Desert Creek (43°03'30"N, 121° 58'W; T.29S, R.6E) on the Chemult Ranger District of the Winema National Forest, approximately 23.5 km southwest (217°) of Chemult, Oregon. The 1404 ha study area is on the east slope of the Cascade Mountains and ranges from 4790 to 5130' (1460 - 1565 m) in elevation. The western edge of the study area is approximately 1.2 km east of Crater Lake National Park. The southern edge of the study area is approximately 0.75 km north of Desert Creek, a class IV intermittent stream, that runs during spring snowmelt and heavy rains.

The Desert Creek study area is predominantly late seral ponderosa pine forest-type. Lodgepole pine is found in the understory of many of the stands and is dominant in some of the stands on the periphery of the study area. The shrub layers within the study area are dominated by bitterbrush. Rabbitbrush (*Haplopappus bloomeri*), manzanita, and snowbrush are found in portions of the study area in lower densities. The herbaceous layers are usually dominated by needlegrass, sedges, or bottlebrush squirreltail (*Sitanion hystrix*).

Approximately 70% of the study area is comprised of stands in the Desert Ponderosa Pine Old-growth Allocation of the Chemult Ranger District (Libercajt 1994). Logging occurred throughout most of the area around 1916. Little or no commercial harvesting has occurred in the study area since that time (Ibid.); however, woodcutting has reduced the density of large snags and down wood. Densities of large ponderosa pine (µ21" dbh) in the Desert Ponderosa Pine Old-Growth Allocation within the study area range from 8 to 22 trees per acre. Approximately 52% of the stands have adequate numbers of large trees for classification as old-growth, but

lack large wood decadence to meet a strict definition (Hopkins et al. 1992a). Approximately 21% (300 ha) of the study area was underburned in 1996 and 1997 as part of a prescription to decrease the understory and shrub layers in the stands of large pine. In 1999 operations to mechanically reduce the understory began in the northeast portion of the study area and continued through 2001. The nearest stands of large trees dominated by sugar pine are located at Lookout Butte, approximately 5.5 km south of the study area (Terry Simpson, pers. comm.).

METHODS

In 2002 I searched for nests of white-headed woodpeckers on the study areas from 3 May to 27 June. I did not search extensively at the Blue Jay study area because it had low densities of white-headed woodpeckers during surveys in 1997 and 1998 (Frenzel and Popper 1998a, 1998b) and no previously known nest sites (Frenzel 1998). I concentrated my nest-searches near nest-territories I located in 1997 – 2001 (Frenzel 1998, 1999a, 1999b, 2000, 2001) and around locations of sightings of white-headed woodpeckers mapped during bird surveys on the study areas in 1997 and 1998 (Frenzel and Popper 1998b). I also searched extensively where I encountered white-headed woodpeckers while traveling through the study areas and in habitats similar to nest-sites I located in previous years. I classified a previously known territory as occupied if I heard or saw white-headed woodpeckers in the area during my nest searches or found signs of excavation typical for the species. I identified a cavity as the nest of a white-headed woodpecker if I saw it occupied by a white-headed woodpecker during daylight hours. To determine use of old nests of white-headed woodpeckers by secondary cavity nesters I re-examined old cavities that I had confirmed as nests of white-headed woodpeckers in 1997-2001. I calculated a minimum density of white-headed woodpeckers at the Metolius study area from the total number of nests I found in 2002 that were inside an area I systematically searched in 1997 (Frenzel 1998).

After 27 May, I re-visited each known active nest of white-headed woodpeckers on the study areas every 1-9 days (mean = 4.8 days, n = 356 visits) until I determined the outcome of the nesting attempts. After a nest had fully feathered young I limited the interval between nest-visits to less than 7 days. At a portion of the nests I examined the interior of the cavity 1-4 times (mean = 1.8, n = 42) during the nesting period to ascertain stage of development and count eggs or nestlings. For cavities less than 2.5 m above the ground I examined the interior of the cavity using an inspection mirror. For higher nests I used a portable video monitor to view the color signal from a pinhole video camera. The pinhole camera was fitted into a cylindrical probe (33 mm in diameter) that I inserted into the entrances of the cavities. The video probe was mounted on a bracket on the end of an extension pole; a mini-flashlight bulb (powered by 2 AA batteries) on the probe illuminated the cavities (see Proudfoot 1996 for a similar design). If I did not see or hear nesting activity during a nest-visit, I examined the nest-cavity with an inspection mirror if I could safely reach the cavity using a ladder or climbing spurs.

I classified a nesting attempt as successful if I saw a nestling with its head outside the entrance to the nest-cavity and I found the cavity vacant on a subsequent visit; if I found a dead nestling during my last visit to a nest, I still classified the nest as successful if fledging of more

than 1 nestling had been imminent at the previous nest-visit and/or I saw or heard a fledgling near the nest-site. All other nests were classified as failures. I used the Mayfield method (Johnson 1979) to estimate daily survival of nests. To calculate nesting success from the daily survival rate, I used a nesting period of 40 days: 14 days for incubation, and 26 days for fledging of young (Garrett et al. 1996). I combined the data on all known nests on the Deschutes and Winema National Forest from 1997 through 2002 (Frenzel 1998, 1999a, 1999b, 2000, 2001) to examine the influence of cavity-height and habitat on nesting success.

In 2002 I banded and color-marked white-headed woodpeckers on the study areas from 25 June to10 July. I captured white-headed woodpeckers in mist nets set near active nests. I waited until nests had feathered young to begin trapping to reduce the risk of causing nesting failures. I banded each captured bird with a U.S. Fish and Wildlife Service band on 1 leg and 1-2 plastic color-bands on the other. The combination of colors and leg-side on each bird was unique for its gender and National Forest. The combinations I used did not duplicate any combinations previously used in the same areas in 1997 – 2001 (Frenzel 1998, 1999a, 1999b, 2000, 2001) or in 1991 and 1993 (R.D. Dixon, pers. comm.).

From 3 May to 27 June, 2002, I extensively searched for white-headed woodpeckers I captured and released in 1997 - 2001; I visited each of these bird's previous territories every 1-9 days and looked for color-bands on the legs of white-headed woodpeckers that I encountered. If I did not locate a specific color-banded white-headed woodpecker by 1 June, I re-visited the bird's old nest-site and used a game-caller to solicit responses from white-headed woodpeckers in the area: I intermittently played a recording of vocalizations and drumming of the species for at least 20 minutes (pointing the speaker in each cardinal direction for approximately 1 minute followed by a 4- or 5-minute silent interval). I used 10-power binoculars or a 20-power spotting scope to look for color-bands on white-headed woodpeckers I saw on the study areas.

If I did not re-sight a previously banded white-headed woodpecker in 2002, I classified the bird's status as a *turnover* if either a) the territory was occupied by an unmarked white-headed woodpecker of the same gender, or b) there was no evidence that the territory was occupied (i.e., no sightings, no vocalizations, and no sign of recent excavation). If there was evidence that the site was occupied, but I could not confirm the identity of the occupant (i.e., I never got close enough to see the bird's legs thoroughly), I classified the status of the previously banded bird as *unknown*.

After the nesting attempts at all the nests I found in 2002 were completed, I visited each nest-site to describe the nest-tree, the nest-cavity, and the surrounding habitat. I used a hand-held GPS unit (Garmin Etrex) to record UTM coordinates for each nest-tree and mapped the locations on U.S. Geological Survey (USGS) base maps (scale 1:24,000). I photographed each nest-tree for future reference. I used a clinometer to measure heights >9 m and a tape measurer for smaller heights.

For each nest-tree I recorded tree species, height, diameter at breast height (dbh), number of boles, height of split in bole, top condition (e.g., full height, broken top), estimated percent of bark remaining on the trunk, hardness of wood (i.e., hard, moderate, soft, or punky), number of branches (in increments of 10), condition of branches (e.g., fine branches intact, long limbs, short limbs, mostly stubs), lean (degrees), direction of lean, number of old cavities,

number of incomplete cavities, and stage of decay. I classified stage of decay as live, partially dead, recently dead (fine limbs still present, mostly sound), middle-aged (fine limbs gone, incipient decay), old snag (few limbs, advanced decay), or decrepit snag (mostly stubs, rotten and weak).

For the nest-cavity used in 2002 on each nest-tree, I recorded height of the cavity, aspect, and relative position to other cavities on the tree. For cavities that I could safely reach with a ladder or climbing spurs, I also recorded diameter of the trunk at cavity-height, vertical and horizontal diameter of the entrance, width of the sill through wood, width of the sill through bark, depth to the back of the cavity from the entrance, and contents of the cavity. I determined if a cavity was recently excavated from the degree of discoloration of the wood at the entrance of the cavity and from the amount of wood chips at the base of the nest-tree.

At each nest-site I recorded elevation, slope, aspect, topography, relief, silvicultural regime, habitat-type, seral stage, number of layers in the understory (seedlings, saplings, poles), and layers in the overstory (small, medium, large, and giant trees). I estimated canopy-closure at each nest-tree by averaging measurements of closure taken from the 4 cardinal points and 4 intermediate points at the base of the nest-tree. I measured closure at each sample point by looking through a tube (diameter = 48 mm, length = 71 mm) with cross hairs on the outer end; I held the tube 70 degrees from horizontal and estimated the proportion of the view comprised of canopy.

I set up a 0.4 ha circular plot around each nest-tree and measured the maximum canopy-height. I estimated the percent shrub-cover by making visual comparisons to charts of foliage cover (Topik et al. 1988:135). I also estimated percent ground-cover consisting of down and dead wood. I recorded species, height, and dbh of all standing snags within the plot that were >6" dbh and ≥ 0.75 m high; to calculate snag densities I defined a snag as ≥1.4 m (4.5') high. I recorded species and dbh of all live trees >9" dbh within the plot, and tallied the number of saplings (1-5" dbh) and poles (5-9" dbh).

I estimated percentages of habitat-types and seral stages on the Boundary Butte and Desert Creek study areas from USDA Forest Service stand exam maps and orthophotos (1:24,000) using a 0.125" (3.175 mm) overlay grid. My description of the Desert Creek study area is based on stand exams available for 66% of the area. I followed Volland's (1988) definitions for plant associations. To be consistent with definitions of old-growth used by Dixon (1995a) I classified stands from definitions by Hopkins et al. (1992a, 1992b) for age and density of large trees. I used Dixon's (1995a, 1995b) descriptions of habitat for the other study areas. I measured distances between nests that were >300 m apart from UTM coordinates.

I constructed 90 and/or 95% confidence intervals (CI) around means from *t*-distributions (Zar 1984:103). I used 2-sample t-tests assuming unequal variances to test differences in heights of nest-trees between the northern and southern study areas. I calculated the correlation between proportional cavity-height (cavity-height/tree-height) and height of the nest-trees using linear regression (Ibid.:263), and tested the significance of the regression using an analysis of variance (Ibid.:269). I assigned a random height to each nest-tree by multiplying tree-heights by random numbers with a uniform distribution between 0 and 1. I tested the significance of differences between cavity-heights and random heights on large nest-trees (≥ median height) and small nest-trees (< median height) using paired sample *t*-tests (Ibid.:150-1).

I tested the significance of differences in survival rates of nests using a Chi-square procedure (Sauer and Williams 1989). All significance tests were conducted with $\alpha = 0.05$.

To estimate the juvenile survival required to have recruitment offset estimated adult mortality, I used the formula: 1 – adult survivorship = mean number of female offspring/female/year × juvenile survival (Ricklefs 1973, cited in Donovan et al. 1995b). I estimated adult survivorship from re-sightings of color-banded birds known to be alive the previous year. I estimated female offspring per female from estimated nesting success and fledglings per successful nest on the study areas (1997 – 2002). I assumed females only made a single breeding attempt per year (Garrett et al .1996), a 50:50 sex ratio of fledglings, and equal fecundity for all age classes.

RESULTS

Locations of nests

During 2002 I searched extensively for active nests at 104 sites (62 on the Deschutes National Forest and 42 on the Winema National Forest) that I considered possible territories of white-headed woodpeckers either because I had frequently seen white-headed woodpeckers there in past breeding seasons (99 sites) or I saw white-headed woodpeckers in the areas during the 2002 breeding season. In previous years (1997-2001) I located active nests at 94 of these territories.

In 2002 I saw or heard white-headed woodpeckers or found sign of their excavations at 61 of the 99 territories I had identified in previous years. I classified occupancy of 1 previously known territory as unknown; I found sign of a partial excavation at the site, but I did not hear or see white-headed woodpeckers in the area and the territory was occupied by other woodpecker species that could have abandoned the excavation. Occupancy of previously known territories by white-headed woodpeckers in 2002 (57.6%) was the lowest recorded during this study (Table 1). Occupancy of known territories has declined 4.3% to 13.2% each year of the study since 1998 (Figure 2).

In 2002 I found an active nest at 90.2 % of the territories occupied by white-headed woodpeckers (Table 1). I found 55 active nests of white-headed woodpeckers on or near 9 of the study areas (Figures 3-13): 36 on the Deschutes National Forest, and 19 on the Winema National Forest. I found 4 nests of white-headed woodpeckers at territories that I discovered for the first time in 2002. Six of the previously known territories I searched had evidence of occupation by white-headed woodpeckers in 2002, but they apparently did not complete excavating a cavity, failed early in the nesting cycle, or otherwise eluded me during the allocated search time. Although the amount of search time spent at each of the study areas was roughly equal, the numbers of nests found at each study area are not absolute measures of nest-densities. Some nests were more difficult to locate than others and required more search-time.

I found relatively large numbers of nests of white-headed woodpeckers at 4 of the study areas: Black Butte (13 nests), Cold Springs (7 nests), and Metolius (6 nests) on the Deschutes National Forest; and Doe Butte (7 nests) on the Winema National Forest. I found 2-5 confirmed nests of white-headed woodpeckers at each of the other 5 study areas that I

searched extensively. At least 3 of the nests I found on the outskirts of the First Creek study area were also within 1 km of the Metolius study area (Figures 5 and 6). Five of the nests I found in 2002 on the Metolius study area were within the confines of a 443 ha area I systematically searched for nests in 1997, and another nest was located 20 m outside of the search-area's boundary. Minimum density of active nests of white-headed woodpeckers on the Metolius study area in 2002 (within the search area defined in 1997) was 0.45 nests/40 ha, the lowest density found on the study area during the duration of this study (1997-2002). Minimum density of active nests of white-headed woodpeckers on the Metolius study area in 1999, 2000, and 2001 was 0.72 nests/40 ha (Frenzel 2001); the density of nests found in 1998 was 1.08 nests/40 ha (Frenzel 1999a), and I reported a density of 0.63 nests/40 ha located during the 1997 field season (Frenzel 1998).

Nearest-neighbor distances between nests of white-headed woodpeckers found at the Metolius study area in 2002 ranged from 126 to 1000 m (n = 6, mean = 480 m). Nearest-neighbor distances between nests of white-headed woodpeckers at the Black Butte study area ranged from 415 to 1590 m (n = 13, mean = 920 m). Nearest-neighbor distances for nests at the Cold Springs study area ranged from 660 to 2230 m (n = 7, mean = 1020 m). Nearest-neighbor distances between nests of white-headed woodpeckers found at the Doe Butte study area ranged from 951 to 2424 m (n = 7, mean = 1430 m).

Many of the nests of white-headed woodpeckers I found in 2002 were relatively close to the locations of nests I found the previous year. In 2001 I found 58 active nests of white-headed woodpeckers on the study areas (Frenzel 2001). In 2002 I found active nests near 43 of these 2001 territories: the nests located in 2002 were an average of 256 m from the previous year's nest (range 0 – 921 m, n = 43). At 8 of the nest-sites relocated in 2001, the active nests were in the same nest-trees used in 2000: 2 on the Deschutes National Forest, and 6 on the Winema National Forest; 3 of these nests were in the same cavity as the previous year. A nest-cavity used at Yoss Ridge in 2002 was also used by white-headed woodpeckers in 1999, 2000, and 2001. A nest-cavity at the Black Butte study area was also used by white-headed woodpeckers 3 years in a row.

I located 28 nests of white-headed woodpeckers in 2002 that were occupied by at least 1 color-marked bird whose nest I located in 2001. Mean distance between the 2001 and 2002 nests of these color-marked birds was 205 m (range 0 – 659 m, n = 28).

Characteristics of nests and nest-sites

All but 2 of the 55 nests of white-headed woodpeckers I found in 2002 were in completely dead trees. I found 1 nest on the Cold Springs study area that was in the dead top of an otherwise live ponderosa pine; another pair of white-headed woodpeckers just south of Camp Sherman excavated their nest-cavity in the trunk of a live aspen (*Populus tremuloides*). All but 7 of the nests found in the previous years of the study (1997-2001, n = 264) were in completely dead trees: in 1998 I found one pair of white-headed woodpeckers that excavated their cavity in a completely live ponderosa pine; in 1999, 2 nest-cavities were in partially dead ponderosa pines; in 2000 I found 1 nest in the dead top of a partially dead ponderosa pine and another under a dead branch near the top of a live ponderosa pine; and in 2001 I found 1 nest

in a dead fork in an otherwise live tree, and another nest in the trunk of a live larch (*Larix occidentalis*).

Nest-trees of white-headed woodpeckers located in 2002 ranged from 1.33 to 43.3 m in height (Table 2; characteristics of all nests from 1997 to 2002 are compiled in Table 3). Dbh of the nest-trees I found in 2002 ranged from 9.3 to 46.5" (23.6 – 118.1 cm). Forty-nine of the nest-trees (89.1%) were ponderosa pines; I found 1 nest in white fir snag (*Abies concolor*), 3 in sugar pine stumps, 1 in a lodgepole pine stump, and 1 nest in a live aspen. The majority (36) of the nest-trees had broken out tops, 13 had their tops intact or nearly intact, and 6 were stumps of harvested trees. One of the nest-cavities on the Boundary Butte study area was in the tipped up root-wad of a fallen tree. All of the nests in stumps with sawed-off tops were located on the Winema National Forest. Three of the nest-trees had split boles – all of these nest-trees were stumps with sawed-off tops.

The condition of the nest-trees was variable: 3.6% were live or partially dead trees, 16.4% were recently dead trees, 69.1% were middle-aged snags, and 10.9% were old snags; 1 of the nests I found in 2002 was in a decrepit snag in an advanced stage of decay. About half of the cavities were in snags with relatively hard exteriors; I classified the wood on 7 (12.7%) of the nest-trees as hard, 6 (10.9%) as moderately hard, 18 (32.7%) as moderate, 17 (30.9%) as moderately soft, 6 (10.9%) as soft, and I classified one of the nest-trees found in 2002 as punky.

Height of the nest-cavities found in 2002 ranged from 0.67 to 22.0 m. Three of the nest-cavities were markedly higher than the rest of the sample, with cavity-heights more than 2 standard deviations (SD) above the mean of 3.41 m (n = 55, SD = 3.68). Eliminating the 3 highest nest-cavities from the sample, mean cavity-height was 2.67 m.

There were significant differences between nests found on the Winema and Deschutes National Forests in 1997 - 2002 for both height of nest-trees and height of nest-cavities. Mean height of nest-trees at study areas on the Winema National Forest (mean = 5.7 m, 4.1 – 7.2 m CI, n = 114) was significantly lower (t = 8.26, df = 300, $P < 0.001$) than heights of nest-trees on the Deschutes National Forest (mean = 14.9 m, 13.3 – 16.5 m CI, n = 203). Mean height of nest-cavities at study areas on the Winema National Forest (mean = 1.9 m, 1.7 – 2.2 m CI, n = 114) was significantly lower (t = 7.13, df = 269, $P < 0.001$) than cavity-heights on the Deschutes National Forest (mean = 4.4 m, 3.7 – 5.0 m CI, n = 203).

The proportional height of nest-cavities within the nest-trees found in 1997 through 2002 on the Deschutes and Winema National Forests was negatively correlated with height of the nest-trees ($P < 0.001$, r = 0.68, n = 317). Mean height of nest-cavities (1.93 m, n = 158) in nest-trees < median height (6.6 m) was significantly higher (P = 0.005, df = 157) than random heights (mean = 1.67 m, n = 158) on the nest-trees. Mean height of nest-cavities (5.0 m, n = 159) in nest-trees ≥ median height was significantly lower ($P < 0.001$, df = 158) than random heights (mean = 9.7 m, n = 159).

In 2002 most of the cavities the white-headed woodpeckers nested in had freshly excavated entrances (87.3%, n = 55); but at least 7 (12.7%) of the nests were in old cavities (completely or nearly completely excavated in a previous year) or excavated through the old entrance of a cavity that was partially excavated in a previous year. In 2002 I found 5 pairs of white-headed woodpeckers (3 on the Winema National Forest, and 2 on the Deschutes

National Forest) nesting in cavities that I had confirmed as occupied nests in 1997 -2001. In 2001 I found 6 pairs of white-headed woodpeckers (4 on the Winema National Forest, and 2 on the Deschutes National Forest) nesting in cavities that I had confirmed as occupied nests in 1997-2000. In 2000 I found 7 pairs of white-headed woodpeckers nesting in cavities that I had confirmed as occupied nests in 1997, 1998, or 1999 (Frenzel 2000).

Most (80.0%) of the nest-cavities of white-headed woodpeckers I found in 2002 were the lowest complete cavity on the snag (average rank from the bottom = 1.38, range: 1-7, *n* = 55). Thirty-six (65.5%) of the nest-cavities were excavated through places on the trunks of the nest-trees where the bark had sloughed off the snags; 19 (34.5%) of the cavity-entrances were excavated through bark.

Elevations at the nest-sites found in 2002 ranged from 2900 to 5500' (884–1676 m, Table 4; characteristics of all nest-sites 1997–2002 are compiled in Table 5).
As in previous years the topography where the nests were located in 2002 was variable: 31 on benches or flats, 12 on buttes or foothills, 7 on ridges, and 5 near riverbanks. Thirteen of the nest-trees found in 2002 had roads within the 0.4 ha plots around the nests; 5 of these nests were within 10 m of the shoulders of paved roads.

In 2002 I found 72.7% of the nests of white-headed woodpeckers in various silvicultural treatments: 7 in partial cuts, 12 in shelterwoods or seed tree cuts, 9 in overstory removals, 7 in clearcuts, and 5 in commercial thins. Fifteen of the nests were in relatively open spots in virtually uncut stands. Forty-three of the nests were in ponderosa pine forest-type, 4 were in mixed pine forest-type, and 8 were in dry mixed conifer forest-type.

The 0.4 ha plots surrounding the nests of white-headed woodpeckers I found in 2002 were usually relatively open (Table 4). Average canopy-closure at the nest-trees was 13.3%. Average density of big trees (>21" dbh) was 6.8 trees/0.4 ha.
The vast majority of trees in the stands around the nest-trees were ponderosa pine: 92.0% of the big trees in the plots were ponderosa pine; and, 86.9% of the small trees (9-21" dbh), 85.6% of the poles (5-9" dbh), and 76.6% of the saplings (1-5" dbh) in the plots were ponderosa pine. Shrub-cover at the nest-sites averaged 14.9%. The cover-species at most of the nest-sites were bitterbrush, manzanita, and/or snowbrush: at 34 of the sites bitterbrush was the predominant cover; at 6 sites manzanita dominated; 10 sites were mostly snowbrush. *Ribes* spp., *Rosaceae,* or other shrubs, or grasses or ferns dominated at the remaining sites.

Nesting chronology and success

Nearly three-quarters (74.6%) of the nests I found in 2002 were still being excavated or in the egg-laying stage when I discovered them (Table 6). I found 5 more of the nests (9.1%) some time during incubation. The rest of the nests already had nestlings by the time I located them.

Although the over-winter and spring conditions preceding the 2002 breeding season were moderate compared to 2001, the onset of nesting by white-headed woodpeckers on my study areas in 2002 was almost identical to the previous year (Table 1.). In 2002 I first detected eggs in nests of white-headed woodpeckers on 25 May. Onset of nesting on the 2 National Forests was nearly synchronous: median fledge date on the Deschutes National Forest was around 8 July; median date of fledgling on the Winema National Forest was around 7 July. I

observed nestlings fledging as early as 26 June in 2002. All of the successful nests in 2002 had fledged young by 13 July.

In 1997 nesting chronologies of white-headed woodpeckers on the Winema and Deschutes National Forests were also similar to each other; median date of fledging was 5 July (Frenzel 1998). In 1998, after an unusually cold and wet spring, nesting on the Deschutes National Forest began approximately 15 days earlier than nesting on the Winema National Forest (Frenzel 1999a). Snowpack in the Oregon Cascades during the winter of 1998/1999 reached record depths, and spring snowmelt at the study areas in 1999 was delayed even later than in 1998 (Natural Resource Conservation Service 1999). Onset of nesting on the Winema National Forest in 1999 began nearly a week earlier than nesting on the Deschutes National Forest; but because of a high failure for early nests in that year, median dates of fledging were similar at the 2 Forests: 15-16 July (Frenzel 1999b). The winter/spring of 1999/2000 in the Cascade Mountains of Central Oregon had milder temperatures and lower snowpack than the previous 3 winters of the study (Natural Resource Conservation Service 2000). Nesting activities by white-headed woodpeckers began earlier in 2000 than in the previous years. In 2000 I detected eggs in nests of white-headed woodpeckers as early as 15 May. Onset of nesting on the 2 National Forests in 2000 was nearly synchronous. The winter/spring of 2000/2001 in the Cascade Mountains of Central Oregon was extremely dry; by some measurements, it was the lowest snowpack on record (Natural Resource Conservation Service 2001). Despite the mild winter, the onset of nesting by white-headed woodpeckers during the 2001 breeding season was about a week later than the previous year.

Of the 55 confirmed active nests of white-headed woodpeckers I found in 2002 on the 2 National Forests, 33 (60.0%) successfully fledged young: 22 of 36 on the Deschutes National Forest; and 11 of 19 on the Winema National Forest. Using the Mayfield method I estimated daily survival of nests in 2001 was 0.985 (Standard Error = 0.00318); estimated nesting success in 2002 was 54.5% (95% CI: 42.0 – 70.6; 90% CI: 43.9 – 67.7%). Nesting success in 2002 was the second highest recorded during the 6 years of this study (Table 1).

Using the Mayfield method I estimated daily survival of nests in 2001 was 0.976 (Standard Error = 0.0043); estimated nesting success in 2001 was 37.4% (95% CI: 26.2 – 53.2; 90% CI: 27.8 – 50.2%). I estimated daily survival of nests in 2000 was 0.984 (Standard Error = 0.0031); estimated nesting success in 2000 was 52.0% (95% CI: 40.4 – 66.8; 90% CI: 42.1 – 64.1%). Estimated nesting success in 1999 was 22.9% (95% CI: 13.9 – 37.4; 90% CI: 15.1 – 34.5%). Estimated nesting success in 1998 was 39.8% (95% CI: 28.2 – 56.0; 90% CI: 29.9 – 52.9%). Estimated nesting success in 1997 was 57.9% (95% CI: 40.6 – 82.3; 90% CI: 43.2 – 77.6%).

Nests from this study (1997-2002) at sites with high densities of large-diameter trees had a significantly higher survival than nests in recently cut sites ($\chi^2 = 12.769$, df = 1, $P < 0.001$). Nests from 1997 through 2002 that were at uncut sites or had densities of big trees (>21" dbh) =12 trees/acre, had an estimated success-rate of 59.6% (95% CI: 48.7 – 72.9; $n = 80$); nests at previously harvested sites or with a lower density of big trees had an estimated success-rate of 37.6% (95% CI: 31.7 – 44.7; $n = 237$). The proportion of nests found in relatively uncut sites was similar in all 5 years data was collected: 0.20 in 1997, $n = 30$; 0.16 in

1998, n = 57; 0.19 in 1999, n = 52; 0.28 in 2000, n = 65, 0.26 in 2001, n = 58, and 0.34 in 2002, n = 55.

The results of the effects of cavity-height on nesting success (1997–2002 data) were inconclusive. Only 4 of 13 pairs of white-headed woodpeckers using nests I found in extremely high cavities (>15 m, more than 3 Standard Deviations above the mean) successfully fledged young: estimated nesting success was 30.1% (95% CI: 12.4 – 71.3). Nests above mean cavity-height (3.48 m) and less than 15 m high, had an estimated success-rate of 51.2% (39.1 – 66.8% CI; n = 62); nests below mean cavity-height had a nesting success-rate of 41.5% (35.3 – 48.7% CI; n = 242). However, survival of nests did not differ significantly with height of the cavities (χ^2 = 2.673, df = 2, P > 0.10).

Success-rate of nest-cavities in stumps of harvested trees did not differ significantly from nest-cavities in other types of nest-trees. Nests from 1997-2002 that were in stumps with sawed-off tops had an estimated success-rate of 43.7% (95% CI: 30.6 – 62.2; n = 45); nests in full-height or broken-top snags had a nesting success-rate of 42.7% (95% CI: 36.8 – 49.5; n = 271).

I made 441 visits to active nest-sites during the nesting season in 2002. I examined the interior of 21 nest-cavities during the incubation period or at hatching; clutch-size ranged from 3 to 5 eggs (mean = 3.67 ± 0.26 CI). I examined 36 nest-cavities after the eggs had hatched; brood-size ranged from 1 to 4 nestlings with an average of 2.70 chicks per nest (2.5 – 2.9 CI). I knew the number of fully feathered nestlings at 26 of the successful nests; by subtracting the dead nestlings I found in the cavities after the other young had fledged, I estimated that successful nests in 2002 fledged an average of 2.58 young per nest (2.27 – 2.88 CI, range: 1-4, Table 1). I estimated that successful nests in 2001 fledged an average of 2.29 young per nest (2.19 – 2.7 CI, range: 1-4). In 2000 the number of fledglings at successful nests averaged 2.63 young per nest (2.3 – 2.9 CI, range: 1-5, n = 30). In 1999 the number of fledglings at successful nests averaged 2.0 young per nest (1.4 – 2.6 CI, range: 1-3, n = 10).

As in previous years I recorded nesting failures of white-headed woodpeckers throughout the nesting period in 2002 (Table 7); 68.2% of the 22 nesting failures I recorded occurred after the eggs had hatched. I could reasonably ascertain the cause of failure at 12 (54.6%) of the nests of white-headed woodpeckers that did not fledge young in 2001. Predation (45.5%) was the most common attributable cause of failure, and I suspected predation at an additional 13.6% of the nests where the cause of failure was uncertain.

While examining nests of white-headed woodpeckers shortly after nesting activity ceased or while measuring nest-trees in July or August, I found 4 nest-cavities that were occupied by mammals: 2 chipmunks (*Tamias* spp.), and 2 golden mantled ground squirrels (*Spermophilus lateralis*, both foraging on the remains of dead chicks); I also found bedding material, a rodent's nest, droppings, or fur in an additional 17 nests. However, 12 of these nests with evidence of rodent occupation successfully fledged young of white-headed woodpeckers prior to examining the nest.

Adult turnover rates

In 2002 I successfully trapped and released 20 adult white-headed woodpeckers at nest-sites: 12 on the Deschutes National Forest, and 8 on the Winema National Forest. I

banded and color-marked 14 of the birds; 6 of the white-headed woodpeckers I captured were previously banded and color-marked.

At the end of the 2001 nesting season I knew of 60 surviving color-marked adult white-headed woodpeckers on the study areas. After the end of the 2002 field season I classified the status of 42 of these birds as surviving, and 18 as turnovers or mortalities. I sighted 43 color-marked birds during 2002; however, I classified 1 of these as a mortality during the hatching stage of nesting after I discovered a pile of adult feathers in a depredated nest-cavity that had been occupied by a color-marked pair of white-headed woodpeckers. Twelve of the color-marked white-headed woodpeckers that I classified as turnovers in 2002 were replaced in their known territories by unmarked birds. Four were classified as turnovers because I couldn't locate any nesting activity within their known territory during the 2002 breeding season.

If site-tenacity and mate-fidelity are high, turnover rates at the nest-sites I monitored should approximate adult mortality rates of white-headed woodpeckers on the study areas. White-headed woodpeckers are presumed to be monogamous; little is known about the duration of their pair-bonds, but mated birds probably remain paired throughout the year (Garrett et al. 1996). From 1997 to 2002 I have not seen an instance of a color-marked bird changing mates when the previous mate was known to have survived, and all the nests of color-marked white-headed woodpeckers I have re-sighted have been within their original territory or an adjacent territory (mean distance from previous year's nest = 256 m, n = 83, range: 0 - 1056 m).

I estimate adult survivorship from 2001 to 2002 was 0.700, the highest recorded during this study (Table 1). As in all previous years (1998 – 2001) I re-sighted a higher proportion of color-marked white-headed woodpeckers on the Deschutes National Forest (estimated survival = 0.718, n = 39) than I did on the Winema National Forest (estimated survival = 0.667, n = 21).

Excluding birds of unknown status from the sample I estimated adult survivorship from 2000 to 2001 was 0.68 (Frenzel 2001); in 2000 I resighted a higher proportion of color-marked birds on the Deschutes National Forest (estimated survival = 0.67, n = 39) than I did on the Winema National Forest (estimated survival = 0.54, n = 24). I estimated adult survivorship from 1999 to 2000 was 0.618 (Frenzel 2000); in 2000 I resighted a higher proportion of color-marked birds on the Deschutes National Forest (estimated survival = 0.71, n = 22) than I did on the Winema National Forest (estimated survival = 0.46, n = 13). For the year 1998 to 1999 I estimated an adult survivorship of 0.50 (n = 32, excluding birds of unknown status from the sample; Frenzel 1999b). I estimated an adult survivorship of 0.67 from 1997 to 1998 (n = 14, excluding birds of unknown status from the sample). Weighted mean annual survivorship for the 5 years (1997 to 2002) was 0.637.

Assuming a closed population, the productivity and adult survivorship at the study areas from 1997 through 2002 are inadequate to maintain population replacement. The mean estimated nesting success from 1997 through 2002 (42.7%) and mean fledglings per successful nest (2.42, n = 110) would require a juvenile survival rate of 0.703 to offset the estimated adult mortality. This required juvenile survival rate is over 10% greater than the estimated adult survival rate in this study. In avian population models, juvenile survival rates are often assumed to be 50% of adult rates (Temple and Cary 1988; Thompson 1993; Donovan et. al 1995a,

1995b), and this convention has been supported empirically (Greenberg 1980, Noon and Sauer 1992).

Attrition of old nest-snags and re-use by secondary cavity nesters

In 2002 I re-visited 246 snags or stumps that white-headed woodpeckers used as nest-trees during a previous year (1997-2001). Thirty-six of the previously used nest-snags were no longer standing in 2002. At 12 of the old nest-trees that were still standing, the cavity previously used by white-headed woodpeckers was destroyed either because the outer shell of wood at the cavity had fallen or burned off, or the upper portion of the snag containing the cavity had broken off. Excluding stumps of harvested trees from the sample, and weighting each nest-tree for the number of years since I first identified it, I estimated that average attrition of nest-trees previously used by white-headed woodpeckers was 5.41% per year (range: 2.2 – 8.0% annual loss). Loss of previously excavated nest-cavities (due to loss of the nest-tree or destruction of the cavity) averaged 7.30% per year (range: 4.4-10.2%).

During the 2002 breeding season I examined the interior of 185 of the cavities previously excavated by white-headed woodpeckers that were in nest-trees that were still standing. I identified sign of fresh use of those cavities by secondary cavity-nesters at 104 of the old nests: 73 nests (39.5%) re-used by birds; and 31 (16.8%) re-used by mammals. An additional 22.7% of the nests showed sign of re-use in a year previous to 2002: 30 (16.2%) with sign of old avian nesting material, and 12 (6.5%) with old bedding material typical of rodent occupation. A total of 78.9% of the exisiting old cavities of white-headed woodpeckers I re-examined had sign of use by secondary cavity-nesters.

Avian re-use of nests of white-headed woodpecker was dominated by mountain chickadees (*Parus gambeli*, 37.9%) and bluebirds (*Sialia mexicana* and *S. currucoides*, 22.3%). Re-excavation of the old cavities by northern flickers (*Colaptes auratus*) accounted for another 15.5% of the avian re-use of the old white-headed woodpecker nests. The old cavities were also re-used by wrens (*Troglodytes* spp., 8.7%), violet-green and tree swallows (*Tachycineta thalassina* and *T. bicolor*, 4.9%), white-headed woodpeckers (4.9%), white-breasted nuthatches (*Sitta carolinensis*, 3.9%), and starlings (*Sturnus vulgaris*, 1.9%).

Mammalian re-use of nests of white-headed woodpeckers was mostly by chipmunks (*Tamius amoenus*, 62.8%) and Douglas squirrels (*Tamiasciurus douglasii*, 23.3%). Sign of use by rodents that I could not identify to species comprised another 11.6% of the mammalian use of the old cavities. One of the old cavities I examined in 2002 was occupied by a flying squirrel (*Glaucomys sabrinus*), and in a previous year I also saw a white-headed woodpecker nest occupied by a bushy-tailed woodrat (*Neotoma cinerea*).

Nests of other primary cavity-excavators

While searching for nests of white-headed woodpeckers on the study areas I also found 86 nests of other primary cavity-excavators occupied by sapsuckers (*Sphyrapicus* spp.), northern flickers, hairy woodpeckers (*Picoides villosus*), black-backed woodpeckers (*P. arcticus*), Lewis's woodpeckers (*Melanerpes lewis*), or nuthatches (*Sitta* spp.) (Tables 8 and 9). The numbers of nests of these species I found are conservative because in 2002 I only searched for nests in territories where I'd previously seen white-headed woodpeckers, and

while I was searching for nests I did not wait to confirm the occupancy of recently excavated cavities that clearly did not fit nest-descriptions of white-headed woodpeckers [e.g., large excavations by northern flickers and pileated woodpeckers (*Dryocopus pileatus)*, excavations in live trees by black-backed woodpeckers, or small cavities of nuthatches]. I saw or heard pileated woodpeckers at Boundary Butte and Metolius, but I did not locate their nests.

DISCUSSION

Nest-sites and densities

In 1997 through 2002 I found the highest densities of nests of white-headed woodpeckers at the Metolius study area; however, nest-densities and occupancy of territories at the study area have diminished during this study. In 1998 I calculated a minimum density of nests of white-headed woodpeckers of 1.08 nests/40 ha (2.16 birds/40 ha) at the Metolius area (Frenzel 1999a). The estimated density of white-headed woodpeckers on that study area from line transect data in 1998 was 1.97 birds/40 ha (Frenzel and Popper 1998b). In 1999 the number of active nests I located on the Metolius study area decreased (0.72 nests/40 ha; 1.44 birds/40 ha): most of the previous year's territories were occupied by adults in 1999, but several pairs apparently did not complete excavating nests. In 2000 I found a density of nests similar to the previous year; however, 3 of the previously known territories on the Metolius study area were unoccupied. In 2001 the density of nesting pairs of white-headed woodpeckers on the Metolius study area was identical to the previous year; however, I only knew of 1 occupied territory on the study area where I did not locate a nest. In 2002 I recorded the lowest nest-density and site-occupancy during this study, despite a search-effort over 15% greater than the previous year.

The Metolius study area also had the highest density of nesting white-headed woodpeckers of Dixon's (1995a, 1995b) study areas on the Deschutes and Winema National Forests. Dixon systematically searched for nests of white-headed woodpeckers at the Metolius study area in 1991 and found an absolute minimum-density of 1.06 birds/40 ha. The Metolius study area ranges from 2800 to 3800' (853-1158 m) in elevation and contains a substantial proportion (59%) of old-growth ponderosa pine forest (Ibid.). Little of this type of habitat remains uncut at lower elevations because of its relatively easy access compared to higher sites.

Although the Metolius study area is primarily Ponderosa pine forest-type, the eastern border of the study area adjoins a slope of mixed conifer that includes a component of Douglas-fir (*Pseudotsugo menziesii*). The western edge of the Metolius study area contains the riparian area of the Metolius River. Dixon (1995b) reported the highest estimated density of white-headed woodpeckers from line-transect surveys at a study area in the Ochoco Mountains that also had a large component of old-growth mixed conifer. Although white-headed woodpeckers are usually associated with Ponderosa pine, the species is found in limited numbers in some areas in Oregon that do not have extensive tracts of pine, such as the Siskiyou Mountains (Marshall 1997). Morrison and With (1987) reported that at a mixed-conifer site in California, white-headed woodpeckers often foraged on the bark of Douglas-fir and other non-pines despite the presence of mature ponderosa pine; they also reported that during their study the white-headed woodpeckers did not feed extensively on pine-seeds during the fall and winter.

The availability of a variety of forest-types near the Metolius study area may be beneficial to white-headed woodpeckers in years their food base in the mono-typic ponderosa pine stands is inadequate.

From 1997 through 2002 I found 57 nests on the Metolius study area at elevations from 2900 to 3300' (884-1006 m) [mean = 3022' (921 m)] - lower than any of the other study areas except First Creek. The high density of nests at Metolius may be influencing the density of white-headed woodpeckers found at the First Creek study area which is only about 1 km to the west. Although the First Creek study area has no old-growth ponderosa pine-forest, from 1997 to 2002 I identified 7 nesting territories in and around the study area. Possible crowding of nest-territories of white-headed woodpeckers at Metolius may contribute to white-headed woodpeckers dispersing into nearby habitats. In 1997, I found 2 successful nests of white-headed woodpeckers on the Metolius study area that were only 147 m apart; and in 2000 I found 2 other territories on the Metolius Research Natural Area that had successful nests only 268 m apart. In 2001 I found active nests on the Metolius study area as close as 331 m apart; and in 2002 2 nests on the study area that were only 125.6 m apart both successfully fledged young.

Nesting habitat

My results on characteristics of nest-sites are similar to those from previous studies of white-headed woodpeckers in the Deschutes and Winema National Forests in Oregon (Dixon 1995a, 1995b). I found white-headed woodpeckers in this study nesting in relatively open areas. Most of the nests were in previously harvested sites; however, it is important not to extrapolate the characteristics of nest-sites to represent the overall habitat-requirements of the species. White-headed woodpeckers use different habitat-types for foraging and roosting than the special sites used for nesting within their home ranges (Ibid.). Habitats other than nesting-sites, such as foraging areas and over-wintering habitat, may be critical to the species. Moreover, the quality of habitats occupied by a species cannot be assumed without demographic information (Van Horne 1983). My research, in particular, shows that white-headed woodpeckers often select nest-sites that result in low success-rates. Saab and Vierling (2001) recently reported that habitat commonly used for nesting by Lewis's woodpeckers was sink habitat (i.e., productivity and juvenile survival did not offset adult mortality).

It has been hypothesized that nest-sites may be limiting for white-headed woodpeckers in managed areas with low snag-availability (Garrett et al. 1996). Availability of nest-trees is undoubtedly a factor affecting the quality of habitat for breeding white-headed woodpeckers; however, the nest-sites used by white-headed woodpeckers in this study suggest that at some study areas other factors may be more important. The study areas on the Winema National Forest have relatively low snag-densities (Dixon 1995a, 1995b). Some of the study areas on the Winema National Forest that contain extensive tracts of older, large ponderosa pines (Blue Jay, Wildhorse Ridge, and Desert Creek) have low densities of white-headed woodpeckers (Frenzel and Popper 1998a, 1998b; Dixon 1995b). In contrast, I found moderate densities of white-headed woodpeckers in heavily managed study areas on the Winema National Forest (Yoss Ridge, Boundary Butte); many of the white-headed woodpeckers I found nesting at these study areas in 1997 through 2002 used uncharacteristically small-diameter nest-trees (5.8-13.4"

dbh, $n = 7$), stumps ($n = 19$), or unusual nest-substrates (e.g., a log in a slash pile, and 3 nests in upturned roots). Some factor other than large tracts of large ponderosa pine or abundance of suitable snags appears to be attracting white-headed woodpeckers to these sites.

Snag-density may be less important for white-headed woodpeckers than other woodpeckers. Most other species of woodpeckers not only nest, but also forage extensively in dead wood. White-headed woodpeckers forage mostly in live trees (Garrett et al. 1996). Snag-densities at nest-sites of white-headed woodpeckers in this study are generally lower than those reported for other species of woodpeckers in similar habitats (Saab and Dudley 1998). White-headed woodpeckers appear to be willing to use a wide range of nest-trees and nest-substrates that would be considered unusual for other species. Milne and Hejl (1989) reported that 28% of the nests of white-headed woodpeckers they found were in leaning or fallen logs; they also reported that the diameter of nest-trees used by white-headed woodpeckers did not differ significantly from the diameter of snags available in their nest-areas.

The high re-use of white-headed woodpecker cavities by avian and mammalian secondary cavity-nesters makes the relationship of snag-density to quality of habitat for white-headed woodpeckers difficult to ascertain. White-headed woodpeckers may not require high snag-densities for good foraging habitat. But, the low density of snags and diminished availability of cavities for other cavity nesters on my study areas may be impacting nesting success of white-headed woodpeckers. I've documented nesting failures of white-headed woodpeckers due to their nest-cavity being usurped by wrens or bluebirds. And a portion of the predation of young of white-headed woodpeckers I've recorded (the major known cause of nest-failure) may be incidental to the mammals usurping the cavities for their own nests or roosts.

Other studies have indicated that white-headed woodpeckers prefer relatively open forest-habitats (see Garrett et al. 1996). As a result of decades of fire-suppression, the quality of the remaining habitat of white-headed woodpeckers in Oregon may be degraded by increasing shrub cover and understory layers (Marshall 1997). This may partially account for the low densities of nesting white-headed woodpeckers in some of the study areas that are mostly old-growth ponderosa pine-forest.

The Wildhorse Ridge area contains extensive tracts of old-growth ponderosa pine (98% of the study area); yet, I only found 3 active nests of white-headed woodpeckers during a systematic search of the area in 1997, and 2 of those nests were in heavy cuts at the outskirts of the study area. During extensive searches of the Wildhorse Ridge area in 1998 I found 3 nesting pairs of white-headed woodpeckers, all in heavy cuts. In 1999 I found 4 actives nests, and in each of the years from 2000 to 2002 I found 3 occupied territories of white-headed woodpeckers near the Wildhorse Ridge study area – all in cuts at the periphery of the study area. The Blue Jay study area is comprised largely of old-growth ponderosa pine (86%) and mature lodgepole pine, but white-headed woodpeckers are infrequently seen there (Dixon 1995a, 1995b; Frenzel and Popper 1998a, 1998b). Estimated densities of white-headed woodpeckers from surveys on line transects were higher on other study areas on the Winema National Forest that contained old-growth ponderosa pine forest interspersed with various silvicultural treatments (Frenzel and Popper 1998a, 1998b); some of the stands on these study areas also contained a component of mature sugar pine.

Some harvested sites on my study areas (e.g. shelterwoods, partial cuts) may more closely visually mimic the open pine-habitat extant prior to modern forest-management than much of the remaining old-growth ponderosa pine. White-headed woodpeckers may be drawn to these areas to reduce their vulnerability to predation. I found evidence of adult-mortality from predation at 7 nests of white-headed woodpeckers during this study: 5 that were likely from mammalian predators inside nest cavities, and 2 near the nest-trees that appeared to be the result of avian predation. When incubating and brooding, adult woodpeckers may be vulnerable to mammalian intruders. When excavating or feeding young with their heads inside the nest-cavity, adult woodpeckers may be susceptible to avian predators. The visibility at open sites may be attractive to the woodpeckers because of the increased time to react to predation attempts. Martin (1993) suggested that pressure from predation may result in use of nest-sites that was different than that randomly available. Li and Martin (1991) suggested that cavity-nesters preferred open sites that allowed visibility for adults to detect and ward off mammalian predators.

Because of increased understories in uncut areas, silvicultural treatments may attract white-headed woodpeckers; however, in this study the productivity of white-headed woodpeckers nesting in these sites was depressed. Nests of white-headed woodpeckers in stands with higher densities of large trees had a nesting success nearly 60% greater than that at other sites.

Density of nest predators and predation rates may be higher in edge habitats (Meffe and Carroll 1994:24-256); and extremely open sites attract bluebirds and other secondary cavity nesters that usurp nests from white-headed woodpeckers (Garrett et al. 1996). Smith (2002) reported that densities of chipmunks in ponderosa pine habitat in central Oregon increased with shrub-cover, and densities of golden-mantled ground squirrels increased with amounts of down wood. I identified both of these mammals as nest-predators of white-headed woodpeckers. Logged areas usually have increased amounts of down wood from slash and the open canopy at harvested sites favors increasing shrub cover. Shrub cover and down wood have increased markedly in the ponderosa pine habitat in central Oregon with continued fire suppression (Marshall 1997).

Adult white-headed woodpeckers nesting in stands with higher densities of large ponderosa pine may also be more attentive to nest-sites because they do not have to range as far to forage. Dixon (1995a, 1995b) reported that white-headed woodpeckers foraged in areas with relatively high (65%) canopy cover, and that white-headed woodpeckers foraged mostly on surfaces of large pines. Bull et al. (1986) suggested that surfaces of large-diameter pines contained more invertebrate prey of white-headed woodpeckers. Mariani and Manuwal (1990) reported that insects in the diets of brown creepers (*Certhia americana*) were more abundant on larger trees that had large fissures in the bark.

Characteristics of nests

White-headed woodpeckers are known for nesting relatively low to the ground (Garrett et al. 1996, Marshall 1997). The heights of the nest-cavities of white-headed woodpeckers in this study (mean on Deschutes National Forest = 4.4 m; mean on Winema National Forest = 1.9 m; mean on both Forests = 3.5 m) are similar to average heights of nest-cavities reported

for this species in other areas (2.8 m, Frederick and Moore 1991; 3.0 m, Milne and Hejl 1989; 2.0 m, Raphael and White 1984). Dixon (1995a, 1995b) reported average cavity-heights for white-headed woodpeckers of 1.4 m and 5 m on the Winema and Deschutes National Forests.

Milne and Hejl (1989) reported that nests of white-headed woodpeckers were closer to the ground than a random selection of heights from nest trees. Nests of white-headed woodpeckers I found in taller snags (≥ median height) also were closer to the ground than random heights; however, in shorter snags, I found that the white-headed woodpeckers excavated at heights higher than randomly selected heights on the snags. It appears that the heights of cavities selected by white-headed woodpeckers are a compromise between pressures from both above and below. Daily (1993) reported that cavity-height of sapsuckers was related to the stage of decay of the nest-tree. White-headed woodpeckers may nest relatively close to the ground simply because they find the conditions suitable for excavating low on the snags they select for nesting; however, nesting relatively close to the ground may be a way for white-headed woodpeckers to partition the available nest-substrates with more aggressive cavity-nesters that shun low nests. Dixon (1995b) attributed a high frequency of white-headed woodpeckers nesting in stumps to intense competition for nest-sites. A consequence of these lower nest-heights, however, may be diminished nesting success (Bull 1978, Li and Martin 1991).

Li and Martin (1991) reported that cavity-nesting species that nested close to the ground had lower success rates, presumably due to higher incidence of predation by mammals. Excluding extremely high nests (greater than 3 SD above the mean), I found that white-headed woodpeckers nesting below mean cavity-height had lower nesting success than those in higher nests; the difference, however, was not statistically significant. Only 4 of 13 nests of white-headed woodpeckers I found in very high cavities (>15 m) successfully produced fledglings; I could not determine the causes of failure at these nests. This lower success-rate may be an artifact of low sample-size; however, high nests of white-headed woodpeckers may be more visible to some predators or they may be influenced by competition with aggressive secondary cavity nesters that are more accustomed to high nest-cavities.

Another possible indication of competition for cavities in this study may be the relatively high re-use of old cavities for nesting by white-headed woodpeckers. Other studies have reported that white-headed woodpeckers usually excavate a new nest-cavity each year (Garrett et al. 1996). Dixon (1995a) found 1 pair of white-headed woodpeckers in 1993 that nested in a cavity that had previously been used by white-headed woodpeckers in 1991. Nearly 20% of the nests of white-headed woodpeckers I found were in re-used cavities or re-excavated old starts. This may be an indication of low availability of preferred nest-snags, but the concurrent low availability of old cavities for secondary cavity-nesters would also increase the competition for new cavities. Some white-headed woodpeckers may be forced to nest in old cavities after their freshly excavated cavities are usurped by other cavity-nesters. Fresh cavities may be desirable to secondary cavity-nesters - especially species with multiple broods - because nesting success at re-used cavities could be impacted by accumulations of parasites. The sounds of excavation or nestlings may attract secondary cavity-nesters to nest-sites of primary cavity-nesters; I saw several interactions between bluebirds and white-headed woodpeckers at nest-cavities (Frenzel 1999a).

The average heights of nest-trees of white-headed woodpeckers in this study (14.9 m on the Deschutes National Forest; 5.7 m on the Winema National Forest) are similar to those reported by Dixon (1995b) for nest-trees found on the Deschutes National Forest (mean = 14 m), but slightly higher than the average height of nest-trees Dixon (1995a) found on the Winema National Forest (3 m). Studies of white-headed woodpeckers in other areas have reported lower averages of heights of nest-trees than those found on the Deschutes National Forest (3.8 m, Raphael and White 1984; 8 m, Milne and Hejl 1989; 5.2 m, Frederick and Moore 1991). The average dbh of the nest-trees of white-headed woodpeckers in this study (68.3 cm) is similar to those reported by other studies (80 cm, Dixon 1995a; 65 cm, Dixon 1995b; 64.6 cm, Raphael and White 1984; 80 cm, Milne and Hejl 1989; 56 cm, Frederick and Moore 1991).

The lower heights of nest-trees on the Winema National Forest can be largely attributed to the higher use of stumps of harvested trees for nesting substrates: 51 of the 114 nests I found on the Winema National Forest were in stumps; only 3 of the 203 nests I found on the Deschutes National Forest were in stumps with sawed off tops. Excluding stumps from the sample, nest-trees on the Winema National Forest had a mean height of 8.9 m (6.5 – 11.5 m CI, $n = 63$). This higher use of stumps on the Winema National Forest is probably due to low snag-availability.

In 1997 I found a pair of white-headed woodpeckers nesting in the upturned root of a lodgepole pine on the Boundary Butte study area; this root had the smallest dbh (14.7 cm) of the nest-trees of white-headed woodpeckers in the study. During 1997 – 2002 I found 7 active nests of white-headed woodpeckers in trees with dbh<18 cm (4 of these nests successfully fledged young). Dixon (1995a, 1995b) reported a minimum dbh of 39 cm for nest-trees of white-headed woodpeckers on the Winema National Forest and 19 cm on the Deschutes National Forest. The dbh of nest-trees of white-headed woodpeckers Milne and Hejl (1989) found in California ranged only as low as 21 cm.

Other studies have reported that white-headed woodpeckers nest in snags that have soft or moderately decayed wood (Dixon 1995a, 1995b; Frederick and Moore 1991; Milne and Hejl 1989; Raphael and White 1984). Many of the nest-trees of white-headed woodpeckers I found during the 6 years of this study ($n = 317$) were in moderate stages of decay, however, I only classified 45 (14.2%) as having soft or punky wood. Most (59.9%) of the nest-trees used by white-headed woodpeckers in this study had exterior wood that was moderately hard. I classified 17.4% of the nest-trees as recently dead, some still holding needles on their branches; and an additional 2.5% were live or only partially dead trees. If white-headed woodpeckers are poor excavators (Marshall 1997) and prefer softer snags for excavating, the relatively high use of recently dead trees for nesting by white-headed woodpecker in this study may also indicate a low availability of preferred snags.

I suspect that the white-headed woodpeckers in this study used nest-trees with a fairly hard outer shell because they provide a protective barrier from intruders. After excavating the entrance through the harder wood, it would be easier for woodpeckers to excavate the larger volume of the body of the cavity in snags that have softer inner wood. White-headed woodpeckers may test snags for a suitable trade-off between interior and exterior hardness of the wood. This may explain the large number of false starts frequently made by excavating

white-headed woodpeckers (Garrett et al. 1996); however, frequency of aborted excavations may also be related to harassment by other cavity-nesters.

The 5 nests of white-headed woodpeckers I have found that were freshly excavated in the base or trunk of live trees are unusual, and may indicate low availability of preferred snags. Milne and Hejl (1989) found 1 nest-cavity of a white-headed woodpecker in a half-dead willow (*Salix* sp.); they reported that they found only 2 references in the literature of white-headed woodpeckers nesting in live trees. Dixon (1995a) found a nest of a pair of white-headed woodpeckers in the dead top of a live ponderosa pine. I also found 3 nests of white-headed woodpeckers in the dead tops of live trees.

Nesting success and survival

During this study (1997 – 2002) winter/spring weather has varied markedly. There was relatively high snowpack on the study areas in January of 1997. Late snowfalls in spring of 1998 delayed snowmelt considerably in many areas compared to 1997. During spring of 1999, record snowpack accumulated in the Cascade Mountains, and snowmelt was even later on the study areas than in 1998. The winter/spring of 1999/2000 was milder than the previous 3 years of this study (Natural Resource Conservation Service 2000), and the winter of 2000/2001 was a drought year with extremely low snowpack in the mountains. These extremes in weather may make many of these years poor representatives of typical nesting by white-headed woodpeckers; however, this broad range in winter/spring severity may have made some of the factors affecting nesting of the species more apparent.

Spring and winter weather may be major factors affecting reproduction and survival in white-headed woodpeckers. The 3 years of this study with moderate spring weather (1997, 2000, and 2002) had the highest nesting success. There was also a mild spring in 2001, but the nesting success in this drought year was low – higher only than the year with the harshest winter. However, adult survivorship from 2000 to 2001 was relatively high - the 2nd highest I estimated during the study. The low snowpack and mild winter in 2000/2001 may have favored over-winter survival, but the succeeding drought conditions in the spring and early summer likely adversely impacted the invertebrate prey populations and diminished the nesting success of the white-headed woodpeckers. The lowest adult survival I estimated followed the harshest winter in this study (1998-1999).

In some years elevation appears to impact the nesting of white-headed woodpeckers. Elevations of nest-sites of white-headed woodpeckers I found on the Deschutes National Forest ranged from 2900 to 4080' (884 –1244 m); elevations of nest-sites on the Winema National Forest ranged from 4610 – 5500' (1405-1676 m). In 1997 onset of nesting by white-headed woodpeckers was nearly simultaneous on the Winema and Deschutes National Forests; this onset was 8 days earlier than onset of nesting in the same areas in 1991 and 1993 (R.D. Dixon, pers. comm.). In 1998 onset of nesting by white-headed woodpeckers on the 2 Forests was 15 days apart: nesting on the Deschutes National Forest began at least a week earlier than the previous year; and nesting on the Winema National Forest was delayed a week from the previous year. It appeared that inclement spring weather delayed nesting by white-headed woodpeckers on the higher elevation sites on the Winema National Forest while it did not cause white-headed woodpeckers on the lower sites on the Deschutes National Forest to delay their

nesting efforts (Frenzel 1999a). In 1999, with even later snowmelt than the previous year, nesting began nearly 2-weeks later than the previous year on the Deschutes National Forest, but nesting on the Winema National Forest was ahead of the lower elevation sites by nearly a week. In 2000, a year with a mild spring, onset of nesting was early and nearly synchronous on the 2 Forests; in 2001, the year with the driest winter, nesting on the 2 Forests was synchronous, but over a week later than the previous year. The cues that white-headed woodpeckers in central Oregon are using to time onset of nesting are not simply day-length or temperature, and the cues appear to vary with elevation.

Onset of nesting may be a product of over-winter condition of the adult females and the availability of a food source in the spring (e.g., emerging insects) to sustain the nesting adults and feed young. White-headed woodpeckers on the 2 Forests may be relying on different insect populations that vary in their response to weather in different years. In addition, seed availability probably differs markedly between the 2 areas in some years (Frenzel 1999a). This complex of factors may account for the unpredictability of onset of nesting at the study areas in 1997 – 2002.

Ligon (1973) suggested that spring was a crucial time for white-headed woodpeckers because seed-crops are depleted and invertebrates are not yet abundant or available. I would expect this bottleneck to be more severe at higher elevations in most years. The increased impact of weather at higher elevation sites in some years may explain differences in sites used by the species on the 2 National Forests in this study. In a summary of the current status of white-headed woodpeckers in Oregon and Washington, Marshall (1996) stated that researchers needed to determine why apparently suitable habitat for the species was unoccupied. Dixon (1995a, 1995b) found no or low densities of white-headed woodpeckers at some study areas on the Winema National Forest that contained extensive monotypic stands of larger, older ponderosa pine; yet, she found moderate to high densities of white-headed woodpeckers in similar habitats on the Deschutes National Forest. I also found moderate to high densities of nests in monotypic stands of ponderosa pine on the Deschutes National Forest, but found some similar sites on the Winema National Forest had few nesting white-headed woodpeckers. I did find moderate densities of white-headed woodpeckers on the Winema National Forest at 3 study areas that had lower proportions of large ponderosa pine; all of these sites, however, also had inclusions of mature sugar pine or pockets of the larger-coned pine nearby (Frenzel and Popper 1998b).

Availability of pine seeds during the fall and winter prior to the breeding season may be impacting nesting success of white-headed woodpeckers in central Oregon. The year with the poorest seed-crop (1998, Jim Barner pers. comm.) was followed by the year with the lowest nesting success by white-headed woodpeckers in this study. In portions of California where white-headed woodpeckers are considered more abundant, white-headed woodpeckers are not common in monotypic stands of ponderosa pine, but are more abundant in stands that contain 2 species of large-coned pines (Garrett et al. 1996, Marshall 1997). It has been suggested that having 2 potential seed-sources provides a back-up food supply for white-headed woodpeckers during years when 1 of the pine species has limited seed-production (Ibid.). However, in some areas in some years, feeding on pine seeds does not appear to be important to white-headed woodpeckers (Morrison and With 1987).

There are no large tracts of mature sugar pine on the study areas on the Deschutes National Forest where I found moderate to high densities of nests of white-headed woodpeckers; however, ponderosa pines are fairly consistent seed-producers at lower elevations in Oregon (Nancy Lankford, pers. comm.). In addition, at these lower elevations invertebrate-prey of white-headed woodpeckers may be more abundant and become available earlier in most years. Adverse weather is the most serious factor affecting seed-crops of conifers in the Northwest (Dobbs et al. 1976:5-9, Eremko et al. 1989:8-9). Pine conelets and pine catkins of ponderosa pine in central Oregon are susceptible to low temperatures and frosts (Sorensen and Miles 1974), and wet weather reduces pollen dispersal and reduces the quantity and viability of ponderosa pine pollen (Eremko et al. 1989:9). At elevations above 3000 to 3500' seed-production of ponderosa pine appears to be less predictable than at lower elevations; there have been relatively poor seed-crops of ponderosa pine at high elevations in Oregon since 1994 (Nancy Lankford, pers. comm.).

It seems likely that seed-crops of ponderosa pine are less consistent at sites on the Winema National Forest than those at the lower elevation sites on the Deschutes National Forest. The reasons for crop failures can vary between species; poor seed-production for 1 species of conifer may sometimes be accompanied by a heavy cone-crop from another species in the same locale (Eremko et al. 1989:8). Field crews on the Winema National Forest have reported consistent cone crops of sugar pine during years of poor seed production in ponderosa pine (Kelly Greer, pers. comm.). At high elevations in Oregon, white-headed woodpeckers may prefer sites that have a 2nd species of large-coned pine (i.e., sugar pine). Dixon (1995a) reported that during the fall of 1993, 3 white-headed woodpeckers from the Wildhorse Ridge area traveled 10-13 km outside their usual territories to forage on seeds of sugar pines.

Dixon (1995a, 1995b) color-marked 23 white-headed woodpeckers on study areas in the Deschutes National Forest in 1991, and 17 white-headed woodpeckers on the Winema National Forest in 1993. In 1997 and 1998 I re-located 4 of these previously marked birds: 2 on the Deschutes National Forest and 2 on the Winema National Forest (Frenzel 1998, 1999a). In 1999, 2 of these birds occupied their previous territories: 1 marked as a juvenile in 1991, and 1 marked as an adult in 1993 (Frenzel 1999b). By the year 2000, this 1991 juvenile was the only color-marked white-headed woodpecker from 1991 and 1993 that I continued to re-sight; and I classified this bird as a turnover in 2001 (Frenzel 2001). These sightings of previously marked white-headed woodpeckers indicate that the birds have strong site-tenacity and have a relatively long potential life span.

From the turnovers of color-marked white-headed woodpeckers on my study areas from 1997 through 2002, I estimated that mean annual adult survivorship was 0.64. Assuming all birds of unknown status in my sample survived, a conservative estimate from the turnovers I documented results in an estimated annual adult survivorship of 0.67. Survivorship in other woodpecker species has been reported in the range of 0.59 to 0.75 (Martin 1995, see Saab and Vierling 2001). Similar published rates of survivorship have been used in models of population stability for some migratory forest-dwelling birds (Donovan et al. 1995b): Ovenbirds (*Seiurus aurocapillus*) – 0.62; Red-eyed Vireos (*Vireo olivaceus*) – 0.56; and Wood Thrushes (*Hylocichla mustelina*) – 0.67.

The highest nesting success I estimated during this study was 57.9% (1997). Three years of the study had nesting success below 40%. The lowest estimated nesting success was 22.9% in 1999. The impact of low nesting success on white-headed woodpecker populations in 1999 was compounded by that year also having the lowest proportion of pairs on occupied territories attempting to nest (and thus excluded from statistics on nesting success, Figure 2).

The success-rates in this study from 1997 through 2002 are considerably lower than rates reported for white-headed woodpeckers nesting in these areas in 1991 and 1993. Dixon (1995a, 1995b) reported a nesting success of 83% (n = 41) on the Deschutes National Forest, and 87.5% (n = 16) on the Winema National Forest. Marshall (1997) stated that this high nesting success indicated predation or cavity robbing were not serious problems for white-headed woodpeckers in these areas. Some of the difference between the nesting success of white-headed woodpeckers I found and that reported by Dixon can be attributed to my methods. To reduce bias towards successful nests, I used the Mayfield method (Johnson 1979) to weight each nest for the length of time it was known to be at risk. Other studies, however, have also reported high rates of nesting success for white-headed woodpeckers; Saab and Dudley (1998) reported that all 12 of the white-headed woodpecker nests they found in their study area in Idaho successfully fledged young.

The mean nesting success I found on my study areas in 1997 to 2002 would require an unreasonably high juvenile survivorship to balance the adult mortality rate I estimated. Weather conditions in Oregon in 1998, 1999, and 2001 may make these atypical years for survivorship and nesting by white-headed woodpeckers. A succession of poor seed-crops of ponderosa pine at higher elevations may also be depressing nesting success of white-headed woodpeckers in some of the study areas by affecting the over-winter condition of the surviving adult birds. The number of failed nests of white-headed woodpeckers in the study areas on the Deschutes and Winema National Forests in 1997 through 2002 show that high rates of nesting success for the species are not a certainty in all habitats or years.

The causes of nesting failures of white-headed woodpeckers are difficult to identify with any certainty. Predation was the most common attributable cause of nesting failure in this study. Nest-predation has been identified as a common cause of nesting failure in cavity nesters (Li and Martin 1991). However, most evidence of predation is circumstantial: freshly eaten carcasses of nestlings may have been scavenged after the nest was abandoned; the presence of rodent pellets in a cavity is only proof that the cavity was occupied by the mammal, not that the potential predator caused the failure. Proximate causes may mask ultimate causes. Low availability of food items of white-headed woodpeckers may require longer foraging bouts by adults; this decreased attentiveness at the nest-site may increase the vulnerability of the nest to predation. Regardless, determining nest predators and predation rates is essential to understanding the nesting biology of a species (Larivière 1999), and the role played by nest-predators of white-headed woodpeckers in central Oregon requires further examination.

Need for further study

The components of the habitat affecting reproductive success and survivorship of white-headed woodpeckers are not completely understood. The presence of old-growth ponderosa pine is clearly important to white-headed woodpeckers in Oregon (Dixon 1995b, Marshall 1997), but the exact relationship to densities and reproductive success of white-headed woodpeckers is unclear (Frenzel and Popper 1998a, 1998b). The availability of a mixed-conifer component may be important to white-headed woodpeckers in some habitat-types in some years. Snag-availability may not be the limiting factor for this species in some habitats. The presence of sugar pine may be important to white-headed woodpeckers at high elevation sites. Nesting success in central Oregon appears to be highly variable; more long-term data on productivity of the species and the factors impacting nesting success is needed. The quality of the habitats occupied by this species cannot be assumed without demographic information (Van Horne 1983).

Other studies have reported that white-headed woodpeckers prefer relatively open forest with low shrub-cover (Garrett et al. 1996). Uncut forests with dense canopy and heavy understory may exclude white-headed woodpeckers (Marshall 1997). The proportion and distribution of relatively open areas that provide nesting sites for this species appear to be important. Because a history of fire-suppression has increased the understory in much of the remaining older ponderosa pine forest, white-headed woodpeckers are attracted to areas with openings created by silvicultural treatments; however, the nesting-success of white-headed woodpeckers nesting at these sites is depressed, most likely because of increased predation and competition with other cavity nesters. The data on nesting of white-headed woodpeckers on the Deschutes and Winema National Forests is highly variable. Average adult survivorship and nesting success from 1997 to 2002 was too low to maintain local populations, and occupancy of known territories has steadily decreased. The effects of years with low survival and productivity on population stability, and its relationship to habitat quality, cannot be determined without continued study.

The habitat occupied by white-headed woodpeckers in central Oregon is continuing to change with time and active manipulations to reduce the understory and shrub cover. Determining the impact of these changes in the habitat requires continued monitoring of the distribution, nesting success, and survival of this species.

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LITERATURE CITED

Bull, E.L. 1978. Specialized habitat requirements of birds: snag management, old growth, and riparian habitat, p.74-82. *In*: R.M. DeGraaf (ed.), Proceedings of a workshop on nongame bird habitat management in the coniferous forest of the western United States. USDA, For. Serv., Pacific Northwest Forest and Range Research Experiment Station, Tech. Rep. PNW-64.

_____, S.R. Peterson, and J.W. Thomas. 1986. Resource partitioning among woodpeckers in northeastern Oregon. USDA, For. Serv. Res. Note PNW-44.

Daily, G.C. 1993. Heartwood decay and vertical distribution of red-naped sapsucker nest cavities. Wilson Bull. 105:674-679.

Dixon, R.D. 1995a. Density, nest-site and roost-site characteristics, home-range, habitat use and behavior of white-headed woodpeckers: Deschutes and Winema National Forests, Oregon. Unpubl. Report. Nongame Proj. No. 93-3-01. Oregon Dep. Fish and Wildl., USDA Deschutes and Winema Natl. Forests. 86pp.

_____. 1995b. Ecology of white-headed woodpeckers in the central Oregon Cascades. M.S. Thesis. Univ. of Idaho, Moscow. 148pp.

Dobbs, R.C., D.G.W. Edwards, J. Konishi, and D. Wallinger. 1976. Guideline to collecting cones of B.C. conifers. B.C. For. Serv./Can. For. Serv., Joint Rep. No.3. Victoria, B.C. 98pp.

Donovan, T.M., R.H. Lamberson, A. Kimber, F.R. Thompson, III, and J. Faaborg. 1995. Modeling the effects of habitat fragmentations on source and sink demography of neotropical migrant birds. Conservation Biology 9:1396-1407.

Donovan, T.M., F.R. Thompson, III, J. Faaborg, and J.R. Probst. 1995. Reproductive success of migratory birds in habitat sources and sinks. Conservation Biology 9:1380-1395.

Eremko, R.D., D.G.W. Edwards, and D. Wallinger. 1989. A guide to collecting cones of British Columbia conifers. Forest Resource Development Agreement (Canada) Report 055. Forestry Canada, Pacific Forestry Centre/B.C. Ministry of Forests, Research Branch. Victoria, B.C. 113pp.

Frederick, G.P., and T.L. Moore. 1991. Distribution and habitat of white-headed woodpeckers (*Picoides albolarvatus*) in west-central Idaho. Ida. Dept. Fish and Game, Boise. 32pp + appendices.

Frenzel, R.W. 1998. Nest-sites and nesting success of white-headed woodpeckers on the Winema and Deschutes National Forests, Oregon in 1997. Unpubl. Report submitted to the Oregon Natural Heritage Program, The Nature Conservancy of Oregon. 25 pp.

_____. 1999a. Nest-sites and nesting success of white-headed woodpeckers on the Winema and Deschutes National Forests, Oregon in 1998. Unpubl. Report submitted to the Oregon Natural Heritage Program, The Nature Conservancy of Oregon. 42 pp.

_____. 1999b. Nest-sites, nesting success, and turnover-rates of white-headed woodpeckers on the Deschutes and Winema National Forests, Oregon in 1999. Unpubl. Report submitted to the Oregon Natural Heritage Program, The Nature Conservancy of Oregon. 49 pp.

_____. 2000. Nest-sites, nesting success, and turnover-rates of white-headed woodpeckers on the Deschutes and Winema National Forests, Oregon in 2000. Unpubl. Report submitted to the Oregon Natural Heritage Program, The Nature Conservancy of Oregon. 51 pp.

_____. 2001. Nest-sites, nesting success, and turnover-rates of white-headed woodpeckers on the Deschutes and Winema National Forests, Oregon in 2001. Unpubl. Report submitted to the Oregon Natural Heritage Program, The Nature Conservancy of Oregon. 52 pp.

_____, and K.J. Popper. 1998a. Estimated densities of white-headed woodpeckers and other woodpeckers in study areas on the Winema and Deschutes National Forests, Oregon in 1997. Unpubl. Report submitted to the Oregon Natural Heritage Program, The Nature Conservancy of Oregon. 29pp.

_____, _____. 1998b. Estimated densities of white-headed woodpeckers and other woodpeckers in study areas on the Winema and Deschutes National Forests, Oregon in 1998. Unpubl. Report submitted to the Oregon Natural Heritage Program, The Nature Conservancy of Oregon. 29pp.

Garrett, K.L., M.G. Raphael, and R.D. Dixon. 1996. White-headed woodpecker (*Picoides albolarvatus*). *In* The birds of North America, No. 252. (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, Penn. and The American Ornithologists' Union, Washington D.C. 24pp.

Greenberg, R. 1980. Demographic aspects of long-distance migration. Pp. 493-504 *in* A. Keast and E.S. Morton (Eds). Migrant birds in the neotropics: ecology, behavior, distribution and conservation. Smithsonian Institute Press. Washington, D.C.

Hopkins, W.E., S. Simon, M. Schafer, and T. Lillybridge. 1992a. Region 6 interim old growth definition for ponderosa pine series. USDA For. Serv. Deschutes N.F., Fremont N.F., and Wenatchee N.F.

_____. 1992b. Region 6 interim old growth definition for grand fir/white fir series. USDA For. Serv. Deschutes N.F., Fremont N.F., and Wenatchee N.F.

Johnson, D.H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Larivière, S. 1999. Reasons why predators cannot be inferred from nest remains. Condor 101:718-721.

Libercajt, G.M. 1994. A fuel treatment proposal to reduce the fire hazard in the Desert Ponderosa Pine Old-growth Allocation: a proposal for the completion of technical fire management. Unpubl. Report. Chemult Ranger District, Winema National Forest, Oregon. 93pp.

Li, P., and T.E. Martin. 1991. Nest-site selection and nesting success of cavity-nesting birds in high elevation forest. Auk 108:405-418.

Ligon, J.D. 1973. Foraging behavior of the white-headed woodpecker in Idaho. Auk 90:862-869.

Mariani, J.M., and D.A. Manuwal. 1990. Factors influencing brown creeper (*Certhia americana*) abundance patterns in the southern Washington Cascade Range. Studies in Avian Biology 13:53-57.

Marshall, D.B. 1997. Status of the white-headed woodpecker in Oregon and Washington. Unpubl. Report submitted to the Audubon Society of Portland, Oregon. 20pp.

Martin, T.E. 1995. Avian life history evolution in relation to nest sites, nest predation, and food. Ecol. Mono. 65:101-127.

Martin, T.E. 1993. Nest predation and nest sites: new perspectives on old patterns. BioScience 43:523-532.

Meffe, G.K., and C.R. Carroll. 1994. Principles of Conservation Biology. Sinauer Associates, Inc., Sunderland, MA. 600pp.

Milne, K.A., and S.J. Hejl. 1989. Nest-site characteristics of white-headed woodpeckers. J. Wildl. Manage. 53:50-55.

Morrison, M.L., and K.A. With. 1987. Interseasonal and intersexual resource partitioning in hairy and white-headed woodpeckers. Auk 104:225-233.

Natural Resource Conservation Service. 2000. SNOWTEL historical data. Website http://www.wcc.nrcs.usda.gov/water/w_data.html.

Noon, B.R., and J.R. Sauer. 1992. Population models for passerine birds: structure, parameterization, and analysis. Pp. 441-464 *in* D.R. McCullough and R.H. Barrett (Eds). Wildlife 2001: populations. Elsevier Applied Science. New York.

Oregon Department of Fish and Wildlife. 1995. Oregon Department of Fish and Wildlife sensitive species. Unpubl. Leaflet. Oreg. Dep. Fish and Wildl., Portland. 8pp.

Proudfoot, G.A. 1996. Miniature video-board camera used to inspect natural and artificial nest cavities. Wildl. Soc. Bull. 24:528-530.

Raphael, M.G., and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildl. Monogr. 86:1-86.

Ricklefs, R.L. 1973. Fecundity, mortality, and avian demography. Pages 336-435 *in* D.S. Farner, ed. Breeding biology of birds. National Academy of Science, Philadelphia.

Saab, V.A., and J.G. Dudley. 1998. Responses of cavity-nesting birds to stand-replacement fire and salvage logging in ponderosa pine/Douglas-fir forests of southwestern Idaho. USDA, For. Serv., Rocky Mountain Res. Stat., Res. Paper RMRS-RP-11.

_____, and K.T. Vierling. 2001. Reproductive success of Lewis's woodpecker in burned pine and cottonwood riparian forests. Condor 103:491-501.

Sauer J.R., and B.K. Williams. 1989. Generalized procedures for testing hypotheses about survival or recovery rates. J. Wildl. Manage. 53:137-142.

Smith, T.G. 2002. Small mammal relationships with downed wood and antelope bitterbrush in ponderosa pine forest of central Oregon. M.S. Thesis. Oregon State Univ., Corvallis. 146 pp.

Sorensen, F.E., and R.S. Miles. 1974. Differential frost tolerance of ponderosa and lodgepole pine megasporangiate strobili. Forest Science 20:377-378.

Temple, S.A., and J.R. Cary. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. Conserv. Biol. 2:340-347.

Thompson III, F.R. 1993. Simulated responses of a forest-interior bird population to forest management options in central hardwood forests of the United States. Conserv. Biol. 7:325-333.

Topik, C., N.M. Halverson, and T. High. 1988. Plant Associations and Management Guide for the Ponderosa Pine, Douglas-fir, and Grand Fir Zones. USDA, For. Serv., Pacific Northwest Region, R6-ECOL-TP-004-88. 134pp.

USDA Forest Service and USDI Bureau of Land Management. 1994. Record of decision on management of habitat for late-successional and old-growth species within the range of the northern spotted owl. Portland, OR.

USDA Forest Service and USDI Bureau of Land Management. 2000. Final Supplemental Environmental Impact Statement for amendment to the Survey and Manage, Protection Buffer, and other mitigation measures standards and guidelins. Portland, OR. 516pp.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47:893-901.

Volland, L.A. 1988. Plant associations of the central Oregon pumice zone. USDA For. Serv., Pacific Northwest Region. R6-Ecol-104-1985.

Wisdom, M.J., R.S. Holthausen, B.K. Wales, D.C. Lee, C.D. Hargis, V.A. Saab, W.J. Hann, T.D. Rich, M. Rowland, W.J. Murphy, and M.R. Eames. 2000. Source Habitats for terrestrial vertebrates of focus in the Interior Columbia Basin: Broadscale trends and management implications. USDA Forest Service. PNW-GTR-485. Portland, OR. 529pp.

Zar, J.H. 1984. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey. 718pp.

Table 1. Population parameters of white-headed woodpeckers nesting on study areas on the Deschutes and Winema National Forests, Oregon, 1997-2002.

	1997	1998	1999	2000	2001	2002
Winter snowpack conditions	Moderate-high	Moderate	Extremely high	Mild-moderate	Drought	Moderate
Spring conditions	Moderate	Cold, wet	Late snowmelt	Moderate	Dry	Moderate
Estimated adult survival	--	0.67	0.50	0.62	0.68	0.70
Known territories searched	39	66	81	90	94	103
Percent occupancy	--	100	95.7	82.5	70.8	57.6
Nests found	30	57	52	65	58	55
Occupied sites w/ nests found	76.9 %	84.9 %	67.1 %	86.8 %	88.2 %	90.2%
Nesting success	57.9 %	39.8 %	22.9 %	52.0 %	37.4 %	54.5 %
Fledglings/success nest	--	2.33	2.00	2.69	2.29	2.58
Onset of incubation						
Low elevation	22 May	14 May	1 June	15 May	26 May	May 26
High elevation	22 May	29 May	26 May	15 May	26 May	May 25
Median fledge date						
Low elevation	5 July	28 June	15 July	27 June	4 July	July 8
High elevation	5 July	13 July	15 July	28 June	3 July	July 7

Table 2. Characteristics of nests of white-headed woodpeckers found in study areas on the Deschutes and Winema National Forests in 2002.

Characteristic	sample size	mean	95% CI	Range
Height of nest-tree	55	11.9 m	± 3.0 m	1.33 – 43.3 m
Dbh of nest-tree	55	70.9 cm (27.9 ")	± 6.6 cm (± 2.6 ")	23.6 – 118.1 cm (9.3 – 46.5 ")
Height of nest-cavity	55	3.41 m	± 0.67 m	0.67 – 21.95 m
Height of nest-cavity*	52	2.67 m	± 0.47 m	0.67 – 9.81 m
Diameter of trunk at cavity	51	67.1 cm (26.4 ")	± 7.1 cm (± 2.8 ")	21.8 – 118.1 cm (8.6 – 46.5 ")
Amount of bark on nest-tree	55	50.3 %	± 10.8 %	0 - 100 %
Lean of nest-tree	55	3.8 °	± 1.7 °	0 - 42 °
Complete cavities in nest-tree	55	2.4	± 0.69	1 – 13
Incomplete excavations	55	2.1	± 0.75	0 - 12
Horizontal diam. of entrance	50	45.8 mm	± 1.11 mm	39.2 – 65.0 mm
Vertical diam. of entrance	50	46.9 mm	± 1.1mm	40.6 – 60.4 mm
Depth to back of cavity	50	134.9 mm	± 8.6 mm	78 - 260 mm
Sill-width of cavity entrance	50	43.3 mm	± 4.2 mm	16.5 – 76.0 mm

* Excludes 3 highest cavities from the sample [>2 standard deviations (SD) above the mean].

Table 3. Characteristics of nests of white-headed woodpeckers found in study areas on the Deschutes and Winema National Forests in 1997 - 2002.

Characteristic	sample size	mean	95% CI	Range
Height of nest-tree	317	11.6 m	± 1.26 m	0.61 – 44.2 m
Dbh of nest-tree[1]	316	68.3 cm (26.9 ")	± 2.8 cm (± 1.2 ")	14.7 – 150.6 cm (5.8 – 59.3 ")
Height of nest-cavity	317	3.48 m	± 0.42 m	0.47 – 30.2 m
Height of nest-cavity[2]	304	2.81 m	± 0.22 m	0.47 – 11.74 m
Diameter of trunk at cavity	273	65.0 cm (25.6 ")	± 3.1 cm (± 1.2 ")	15.7 – 150.6 cm (6.2 – 59.3 ")
Amount of bark on nest-tree	317	49.2 %	± 4.3 %	0 - 100 %
Lean of nest-tree	317	4.2 °	± 1.2 °	0 - 114 °
Lean of nest-tree[3]	315	3.5 °	± 0.7 °	0 - 57 °
Complete cavities in nest-tree	317	2.3	± 0.22	1 - 15
Incomplete excavations	317	2.4	± 0.33	0 - 17
Horizontal diam. of entrance	273	45.6 mm	± 0.4 mm	39.2 – 65.0 mm
Vertical diam. of entrance	272	46.4 mm	± 0.5 mm	35.0 – 82.4 mm
Depth to back of cavity	273	133.4 mm	± 3.1 mm	75 - 260 mm
Sill-width of cavity entrance	274	41.8 mm	± 1.6 mm	6.0 – 81.0 mm

[1] Excludes a nest in the wall of a pumphouse from sample.
[2] Excludes 13 highest cavities from the sample [>3 standard deviations (SD) above the mean].
[3] Excludes 2 nests in a fallen tree from sample.

Table 4. Characteristics of nest-sites of white-headed woodpeckers found in study areas on the Deschutes and Winema National Forests in 2002.

Characteristic	sample size	mean	95% CI	Range
Elevation (Deschutes N.F.)	36	966 m (3169 ft)	± 26.4 m (± 86.6 ft)	884 - 1244 m (2900-4080 ft)
Elevation (Winema N.F.)	19	1508 m (4947 ft)	± 28.9 m (± 94.7 ft)	1408 - 1676 m (4620-5500 ft)
Slope	55	5.9 %	± 1.7 %	0 – 28.0 %
Canopy-closure at nest-tree	55	13.3 %	± 4.2 %	0 – 57 %
Maximum canopy-height	55	34.6 m	± 2.1 m	15.8 – 47.2 m
Shrub-cover	55	14.9 %	± 3.9 %	0 - 70 %
Density of trees >21" dbh	55	6.8 trees/0.4 ha	± 1.7	0 - 24
Density of trees 32-48" dbh	55	1.8 trees/0.4 ha	± 0.7	0 - 14
Density of trees 21-32" dbh	55	5.0 trees/0.4 ha	± 1.3	0 - 19
Density of trees 9-21" dbh	55	23.1 trees/0.4 ha	± 5.2	0 - 67
Density of poles 5-9" dbh	55	22.7 trees/0.4 ha	± 5.8	0 - 80
Density of saplings 1-5" dbh	55	66.0 trees/0.4 ha	± 21.9	0 - 411
Density of snags >6" dbh	55	4.4 trees/0.4 ha	± 1.6	0 – 31
Density of snags 6-21" dbh	55	2.8 trees/0.4 ha	± 1.4	0 – 31
Density of snags >21” dbh	55	1.6 trees/0.4 ha	± 0.4	0 – 7

Table 5. Characteristics of nest-sites of white-headed woodpeckers found in study areas on the Deschutes and Winema National Forests in 1997 - 2002.

Characteristic	sample size	mean	95% CI	Range
Elevation (Deschutes N.F.)	203	974 m (3196 ft)	± 10.2 m (± 33.6 ft)	884 - 1244 m (2900-4080 ft)
Elevation (Winema N.F.)	114	1503 m (4930 ft)	± 9.9 m (± 32.6 ft)	1405 - 1676 m (4610-5500 ft)
Slope	317	7.9 %	± 0.8 %	0 – 39.5 %
Canopy-closure at nest-tree	317	10.5 %	± 1.4 %	0 – 65.0 %
Maximum canopy-height	317	32.9 m	± 1.1 m	0 – 51.8 m
Shrub-cover	317	15.9 %	± 1.5 %	0 - 70 %
Density of trees >21" dbh	317	5.8 trees/0.4 ha	± 0.6	0 - 25
Density of trees 32-48" dbh	317	1.3 trees/0.4 ha	± 0.2	0 - 14
Density of trees 21-32" dbh	317	4.4 trees/0.4 ha	± 0.5	0 - 22
Density of trees 9-21" dbh	317	19.1 trees/0.4 ha	± 1.8	0 - 71
Density of poles 5-9" dbh	317	25.1 trees/0.4 ha	± 2.9	0 - 170
Density of saplings 1-5" dbh	317	90.0 trees/0.4 ha	± 12.3	0 - 769
Density of snags >6" dbh	317	4.1 trees/0.4 ha	± 0.6	0 – 41
Density of snags 6-21" dbh	317	2.5 trees/0.4 ha	± 0.5	0 – 32
Density of snags >21” dbh	317	1.5 trees/0.4 ha	± 0.2	0 - 13

Table 6. Stage of development at time of discovery of nests of white-headed woodpeckers found in study areas on the Deschutes and Winema National Forests in 2002.

Stage of development	number of nests
Excavating	38
Egg laying	3
Early incubation	5
Middle incubation	0
Late incubation	0
Hatching	2
Early brooding	4
Nestlings with pin feathers	1
Feathered nestlings	2
Total	55

Table 7. Estimated stage of development at time of failure of nests of white-headed woodpeckers found in study areas on the Deschutes and Winema National Forests in 2002.

Stage of development	number of nests
Excavating	0
Egg laying	4
Early incubation	2
Middle incubation	0
Late incubation	1
Hatching	1
Early brooding	1
Nestlings with pin feathers	7
Feathered nestlings	6
Total	22

Table 8. Confirmed nests* of primary cavity excavators found on study areas in the Deschutes National Forest in 2002.

	Study Area			
Species	Black Butte	Cold Springs	First Creek	Metolius
Sapsucker spp.	1	1	0	0
Black-backed woodpecker	1	0	0	0
Hairy woodpecker	12	3	1	1
White-headed woodpecker	13	7	5	6
Northern flicker	5	3	2	2
Lewis' woodpecker	0	2	0	0
Nuthatch spp.	4	2	1	4

* Numbers of nests found are not measures of relative densities because of unequal search efforts between study areas and species.

Table 9. Confirmed nests* of primary cavity excavators found on study areas in the Winema National Forest in 2002.

	Study Area				
Species	Boundary Butte	Desert Creek	Doe Butte	Wildhorse Ridge	Yoss Ridge
Sapsucker spp.	0	0	1	0	0
Black-backed woodpecker	0	0	0	0	0
Hairy woodpecker	2	3	8	1	0
White-headed woodpecker	3	3	7	2	2
Northern flicker	0	4	6	2	1
Nuthatch spp.	2	3	3	4	1

* Numbers of nests found are not measures of relative densities because of unequal search efforts between study areas and species.

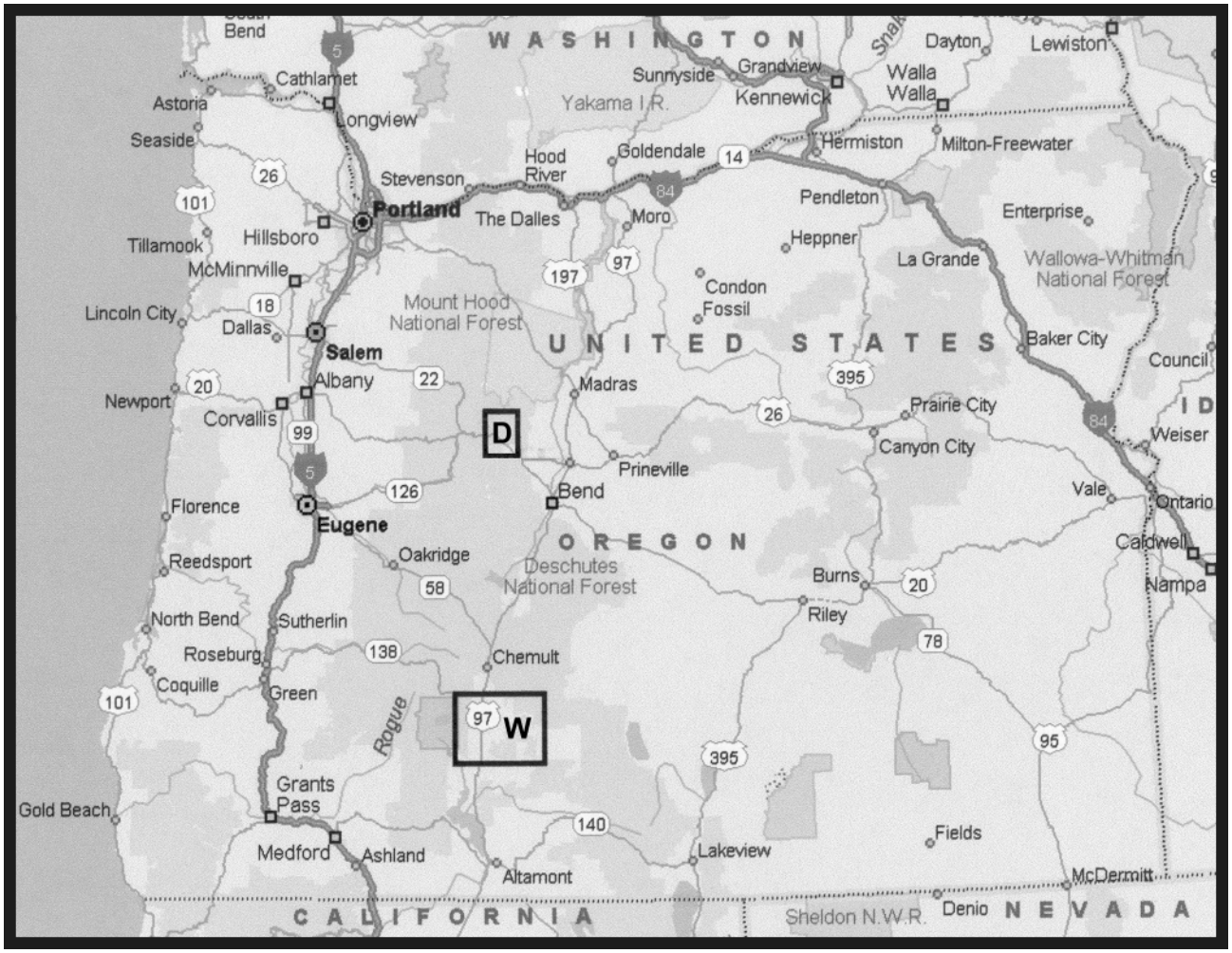

Figure 1. Map of areas encompassing study areas on the Deschutes National Forest (D) and the Winema National Forest (W) in Oregon.

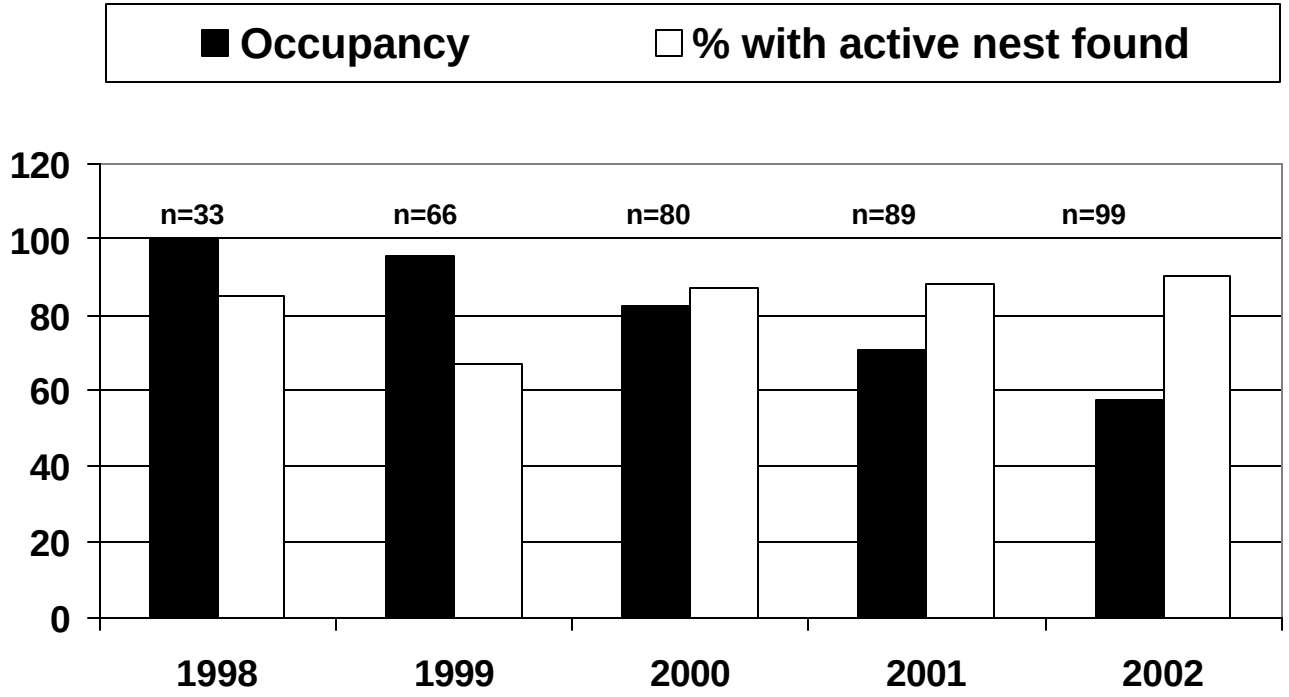

Figure 2. Percent occupancy of previously known white-headed woodpecker territories and percent of occupied sites where an active nest was found, 1998-2002.

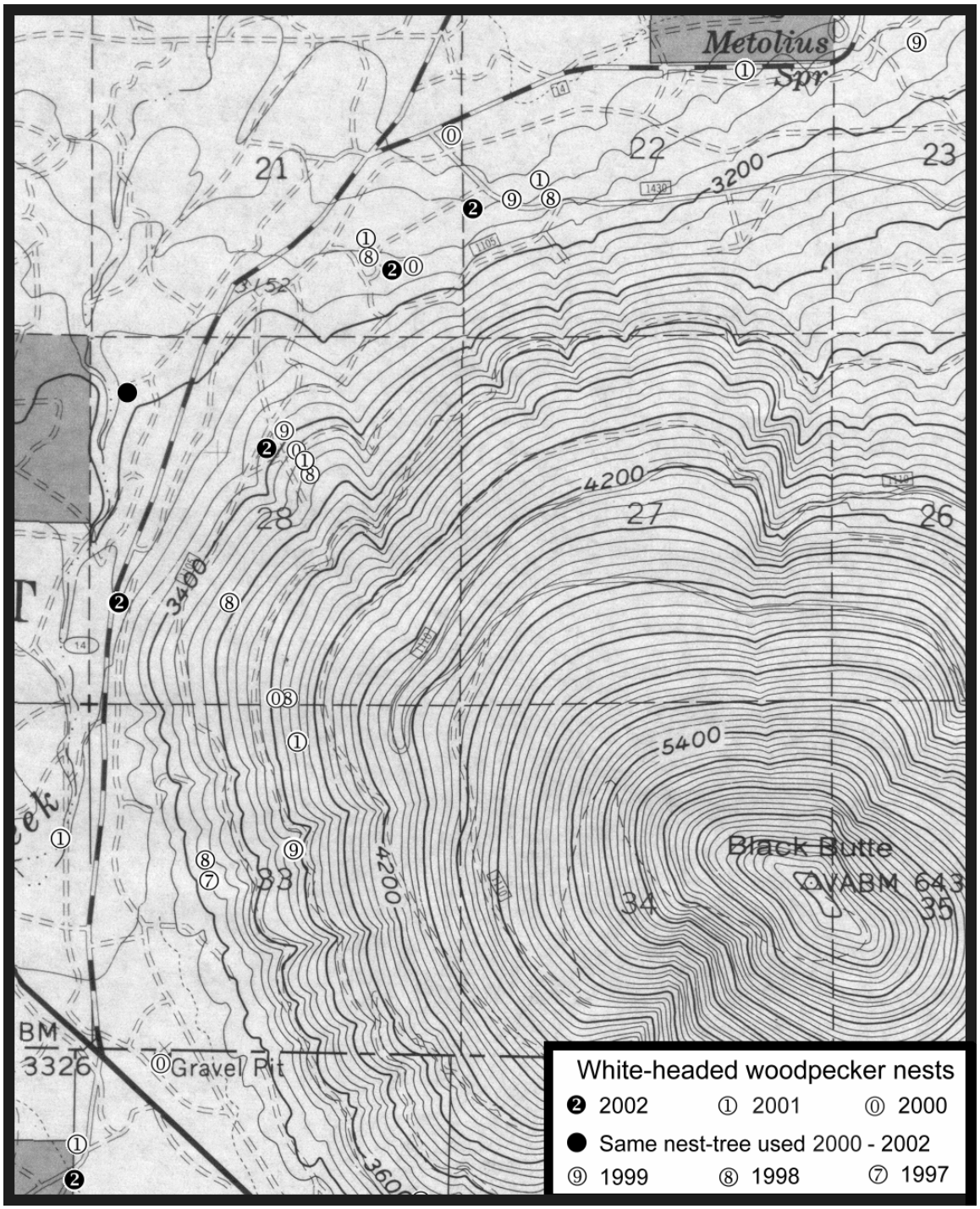

Figure 3. Nests of white-headed woodpeckers found on the northern portion of Black Butte study area (portion of Black Butte Quadrangle).

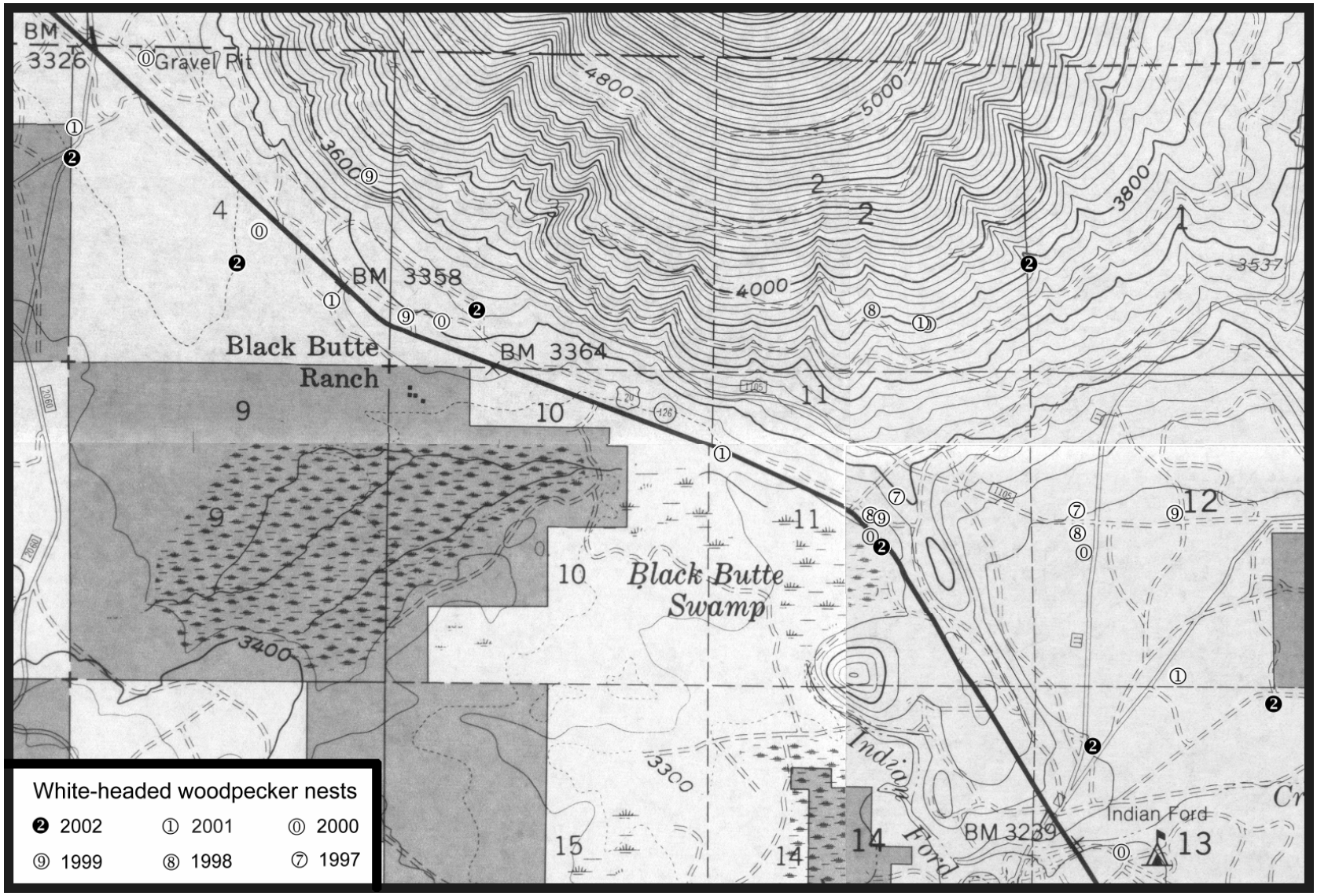

Figure 4. Nests of white-headed woodpeckers found on the southern portion of Black Butte study area (portions of Black Butte, Little Squawback, Black Crater, and Sisters Quadrangles).

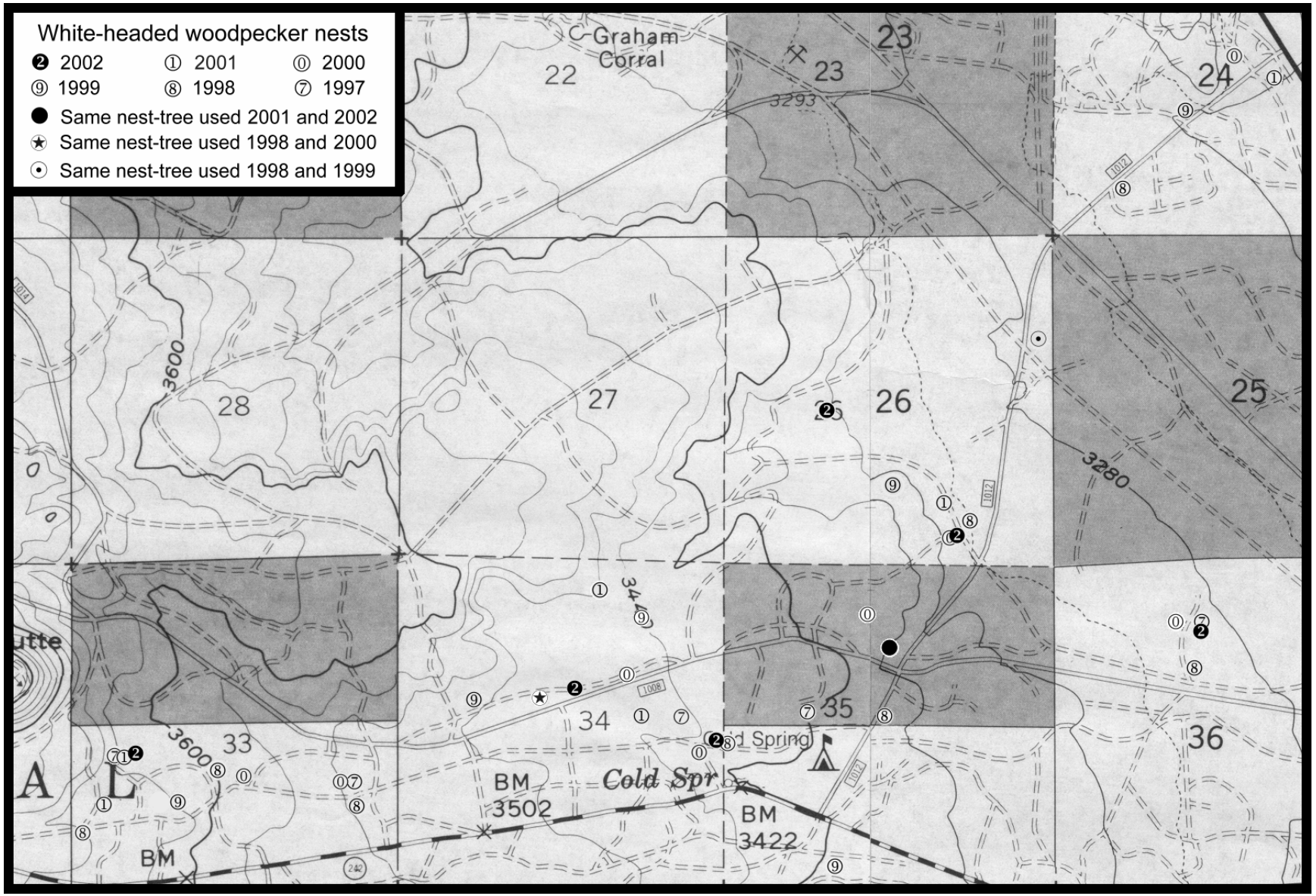

Figure 5. Nests of white-headed woodpeckers found on Cold Springs study area (portions of Black Crater and Sisters Quadrangles).

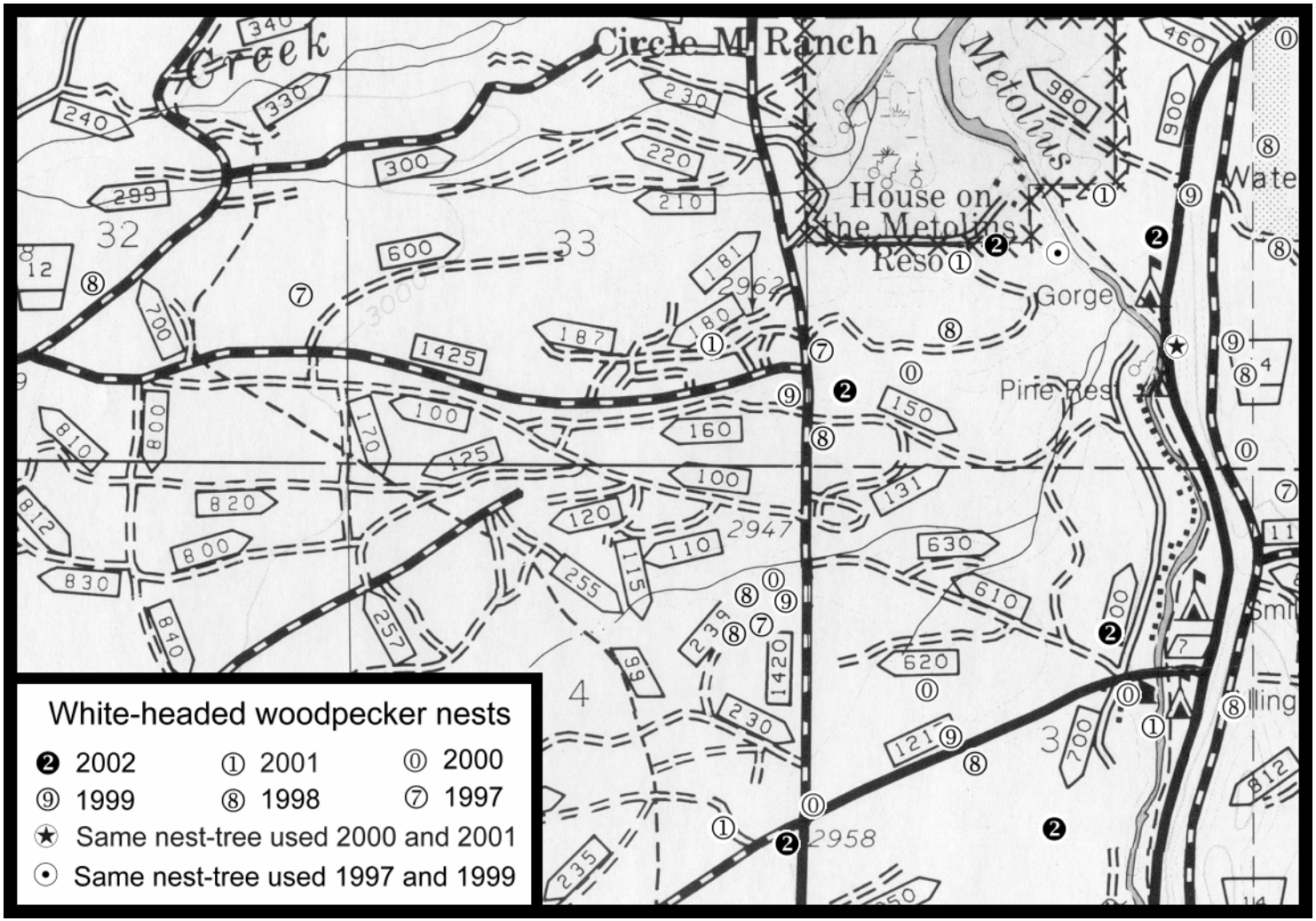

Figure 6. Nests of white-headed woodpeckers found on First Creek study area (portion of Black Butte Quadrangle).

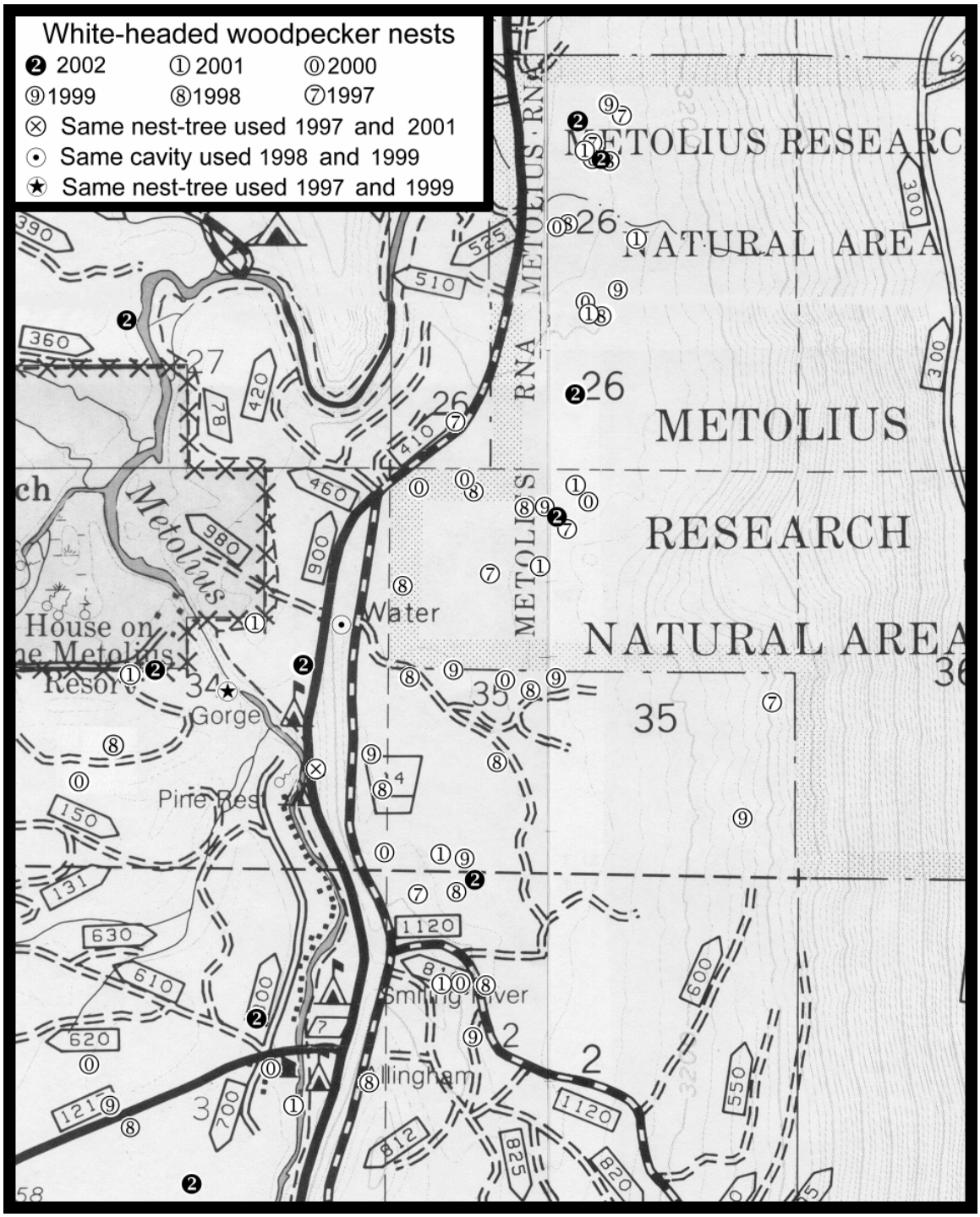

Figure 7. Nests of white-headed woodpeckers found on Metolius study area (portions of Candle Creek, Prairie Farm Springs, Black Butte, and Little Squawback Quadrangles).

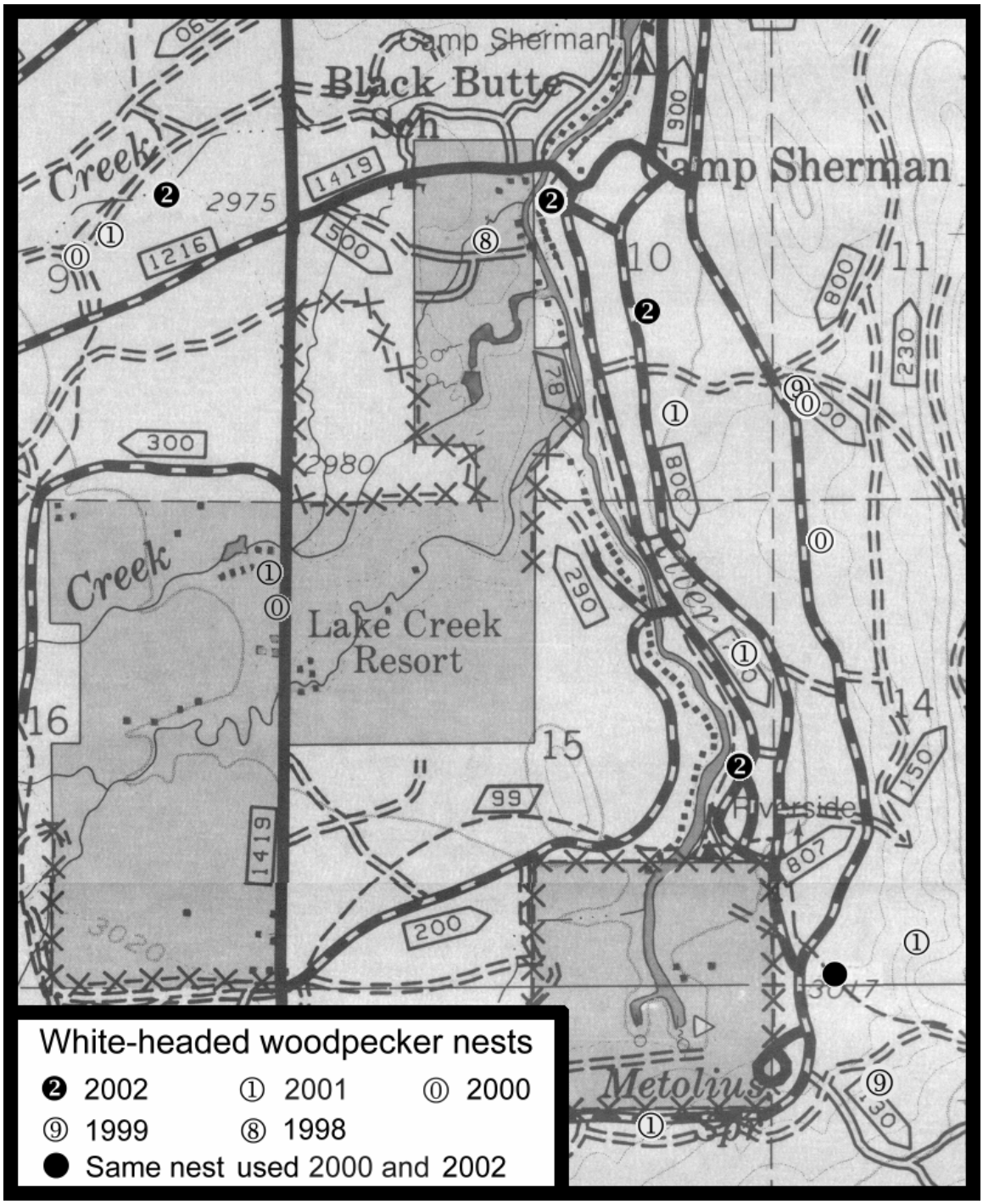

Figure 8. Nests of white-headed woodpeckers found near Camp Sherman between the Metolius and northern Black Butte study areas (portion of NW Sisters Quadrangle).

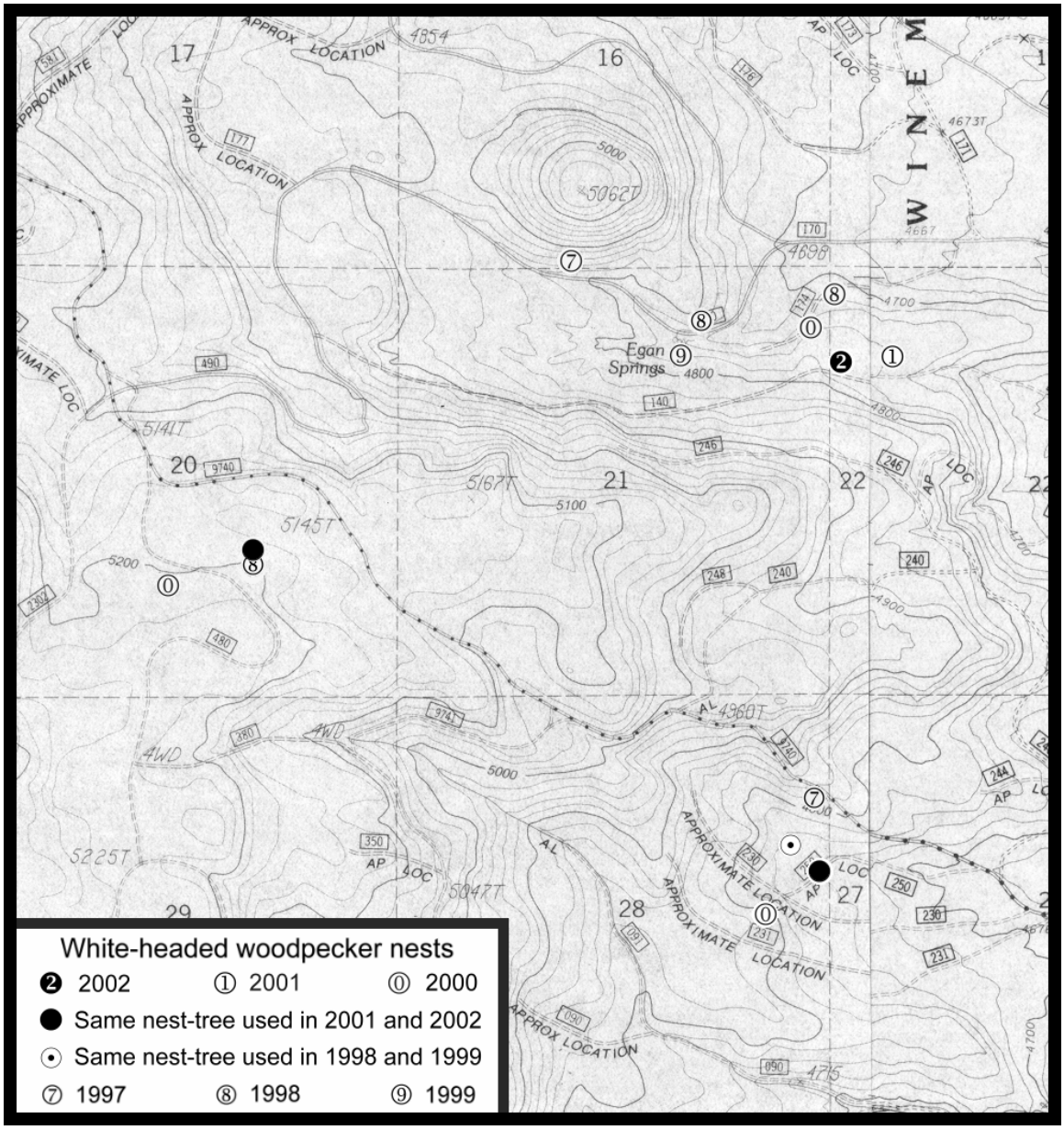

Figure 9. Nests of white-headed woodpeckers found on Boundary Butte study area (portion of Sun Pass Quadrangle).

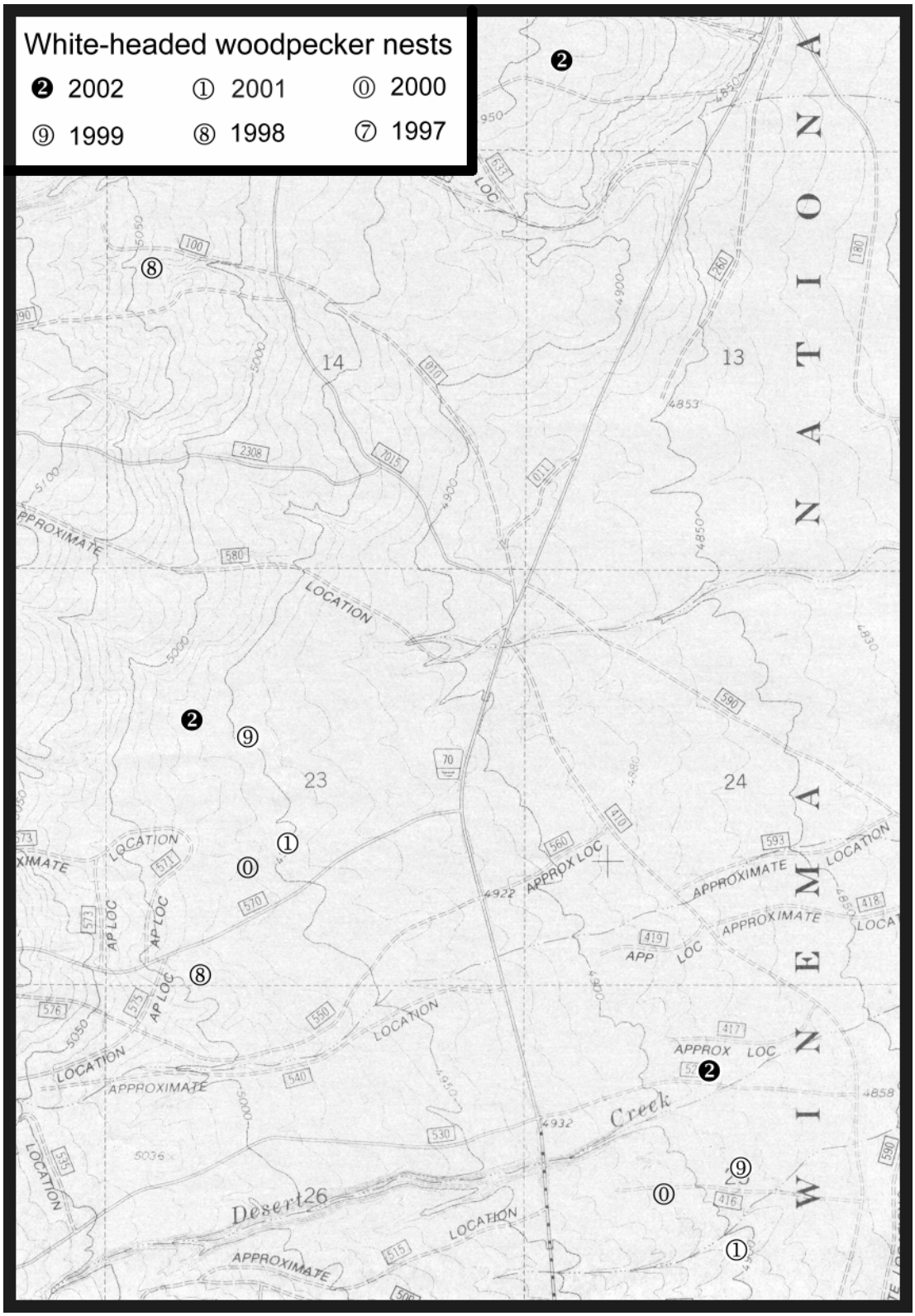

Figure 10. Nests of white-headed woodpeckers found on Desert Creek study area (portion of Welch Butte Quadrangle).

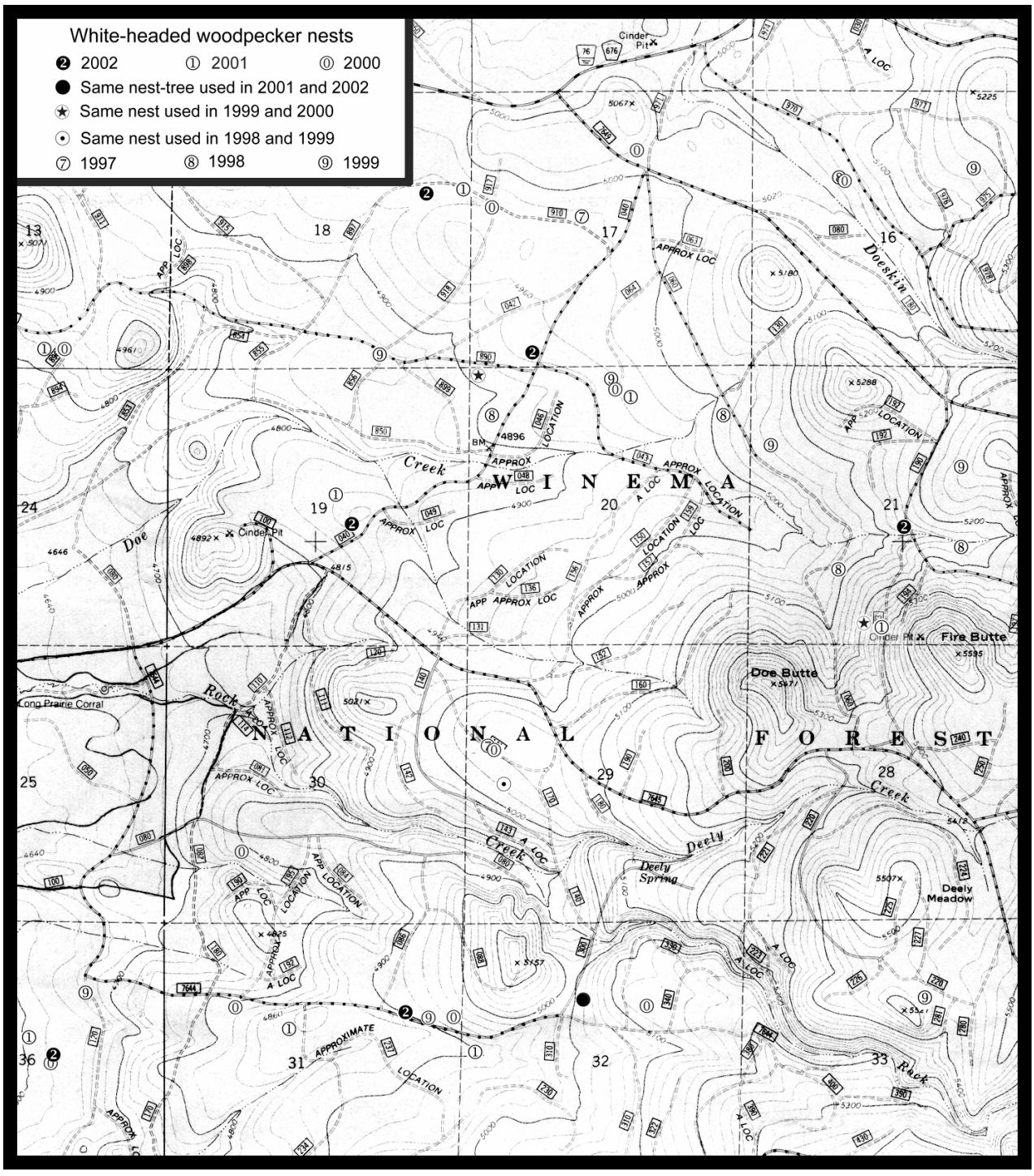

Figure 11. Nests of white-headed woodpeckers found on Doe Butte study area (portion of Bear Butte Quadrangle).

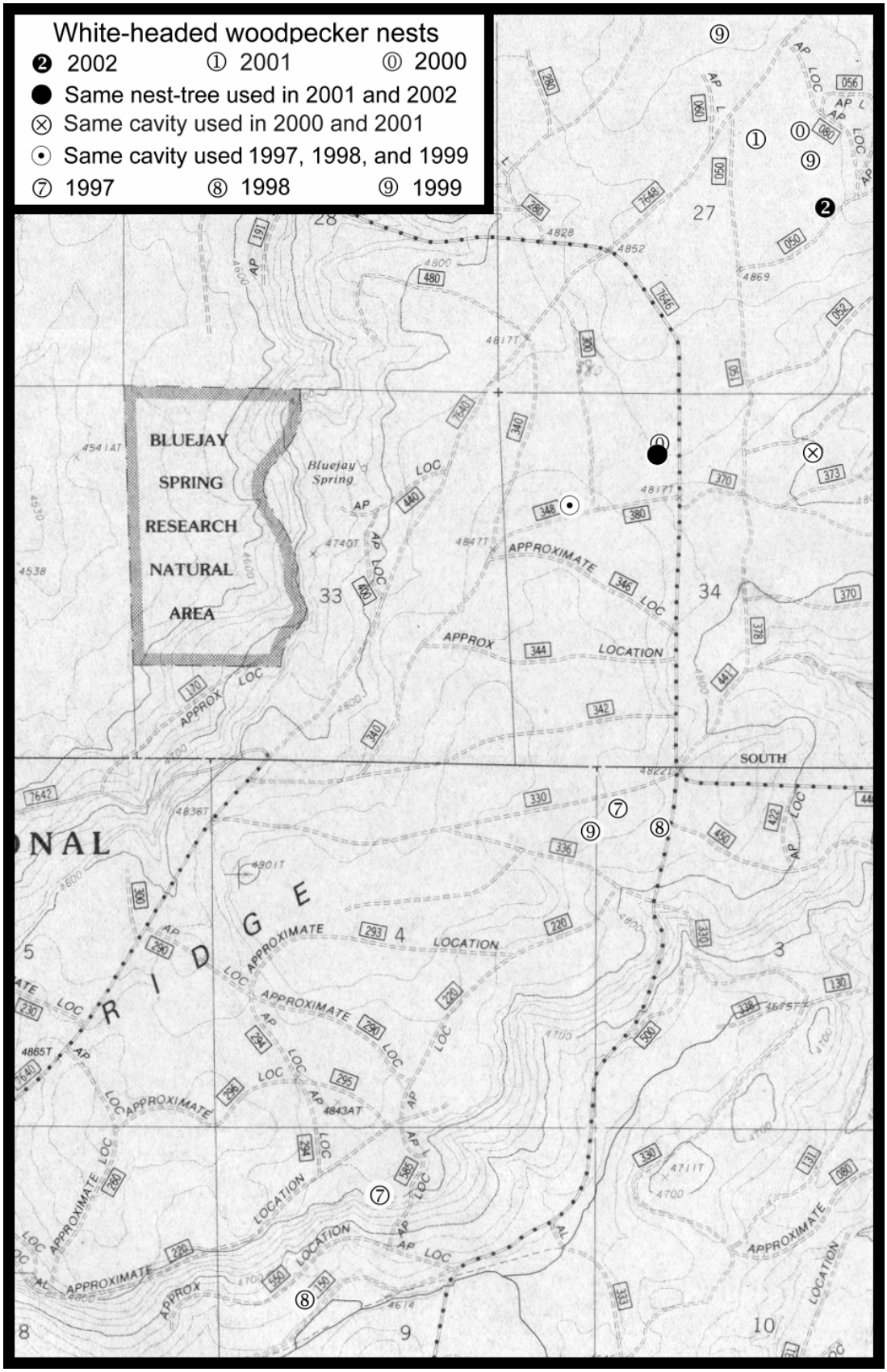

Figure 12. Nests of white-headed woodpeckers found near Wildhorse Ridge and Blue Jay study areas (portion of Wildhorse Ridge Quadrangle).

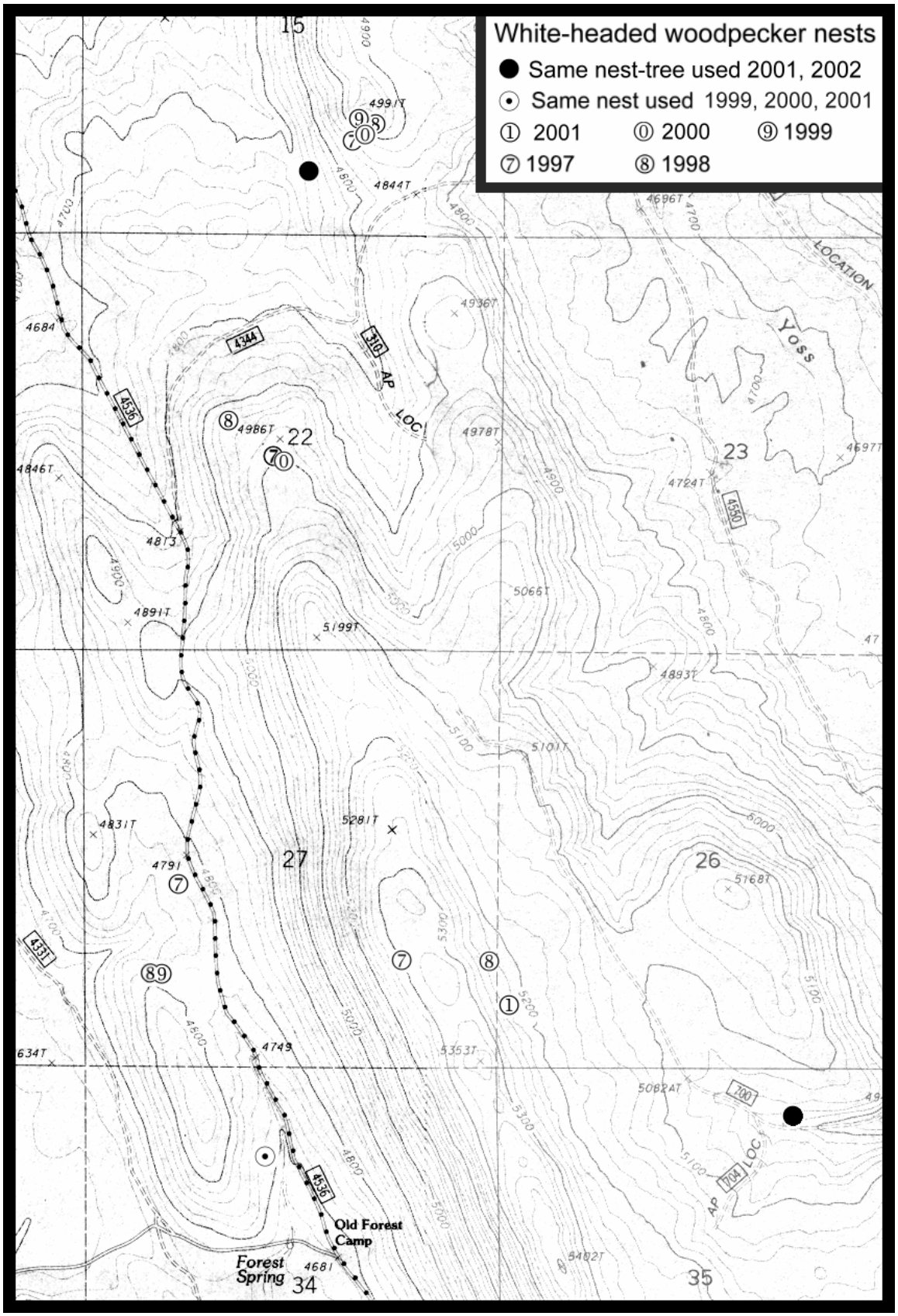

Figure 13. Nests of white-headed woodpeckers found on Yoss Ridge study area (portions of Wocus Bay and Buckhorn Springs Quadrangles).